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A STUDY OF THE GENUS *COLOPHON* GRAY (*COLEOPTERA, LUCANIDAE*).

By K. H. Barnard, D.Sc., F.L.S., F.R.S.S.Afr.

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(With Plate I and Text-figs. 1–10.)

The purpose of this paper is to indicate some of the results of the investigations of the Fauna of the High Mountain Ranges of the Cape Province on which I have been engaged for some years and for which I have received the following research grants: From the Royal Society of South Africa in 1917, and from the Research Grant Board in 1926 and 1928. Acknowledgments are herewith tendered to the Royal Society and the Research Grant Board.

The new species which have been collected are herein described, and attention is drawn to some aspects of the peculiar distribution of this interesting genus.

The attention of entomologists and collectors is especially directed to the necessity for collecting these insects without delay, because the mountains where they live are subject to the destructive practice of veld-burning, in consequence of which every year probably numerous individuals, or even whole colonies, are extinguished.

These beetles live on the summits of the mountain ranges,* and the only people likely to come across them are mountaineers and naturalists with mountaineering tastes. Even these people do not as a rule have the opportunity of spending any great length of time on the summits, and as the beetles seem to be mainly nocturnal, living examples are rarely found. I have therefore in my expeditions concentrated on a method of collecting which may be mentioned here as a hint to other collectors. Although the examples thus obtained are dead and often disjointed, yet they are amply sufficient for specific diagnosis, and allow us to gain an idea of the coleopterous fauna of a locality for which we may otherwise wait for years, or altogether fail to obtain before the beetles become wholly obliterated.

Under the stones on the tops of peaks or outstanding buttresses, especially those lying partly against clumps of grass or rushes, or other low vegetation,

* Gray could have chosen no more appropriate name for this genus of peak-dwellers.

will be found an accumulation of vegetable debris, excrement of millipedes, and the chitinous parts of various insects, millipedes, scorpions, spiders. Where no stones are found the clumps of grass or rushes may be turned back. Turning over stones is, of course, not a new method, but the careful examination of the debris will often yield parts, if not whole specimens, of the very insect for which the collector is searching, and for a living example of which he may search in vain.

The cause of these accumulations seems to be the heaping up in sheltered corners of vegetable remains by the wind, and many beetles probably die natural deaths in their places of concealment. Spiders' webs help to bind the material together. But I am inclined to think that scorpions capture insects while on their nocturnal rambles, and retire to their homes beneath stones to devour them, thus forming "kitchen-middens." On two occasions I have found a scorpion (*Opisthognathus asiaticus*) beneath a stone actually devouring a beetle; in the one case a Tenebrionid, in the other a weevil.

Whatever the cause of these accumulations, they are invaluable to the coleopterist.

South Africa is notably poor in Stag-beetles (*Lucanidae*). As the larvae are internal wood-feeders, the family is essentially prevalent in forest areas, and in South Africa is confined for the most part to the Eastern Province, Natal, Transvaal, and Rhodesia. In these regions there are six species which are representatives of widely distributed subfamilies, either Palaearctic or Circumtropical. With these forms we are not here concerned.

In addition there is in the S.W. Cape the peculiar genus *Colophon*, which, according to Parry (1864, *loc. cit.*, *infra*) and van Roon (1910, *loc. cit.*, *infra*), belongs to the group or subfamily *Chiasognathinae*, whose distribution extends over South America, Australia, New Zealand, and New Guinea. Under the name *Lamprimini* this grouping is accepted by Handlirsch (in Schröder, Handb. Entom., iii, p. 695, 1924), though I believe that it is not accepted by all coleopterists. The classification of the family has not been thoroughly revised since Parry.

While one cannot suggest a Gondwanaland origin for any of the beetles of this family, as in Handlirsch's opinion the evolution of the *Lucanidae* took place only in post-Cretaceous times (Foss. Insekt., Lief. 9, p. 1279, and tab. vii, 1908), yet according to the same author some of the most ancestral forms are to be looked for in the subfamily *Lamprimini* (*Chiasognathini*) (in Schröder, Handb. Entom., iii, p. 695, 1924).

Handlirsch indeed claims the fossil *Palaeognathus succini* Waga, 1883 (Baltic amber, Oligocene), as a Chiasognathine (Foss. Insekt., Lief. 9, p. 1356), though Waga considered it a Cladognathine. Until coleopterists shall have agreed that the *living Lamprimini* (*Chiasognathini*) constitute a natural phyletic group, the correct position of even a well-preserved fossil

should be left in abeyance ; and the assumption, based on Handlirsch's opinion, that the *Lamprimini* were once widely distributed over the world (*cf.* S. Afr. Journ. Sci., xxv, p. 344, 1928) is to be strongly deprecated.

We have no certain knowledge of the origin or history of the genus *Colophon*, but we can endeavour to approach the question by seeking out the exact present-day habitats and distribution of the several species.

Acknowledgments and thanks are due to Dr. Arrow (British Museum), Dr. Eltringham (Oxford), Dr. Andreae (Cape Town), and Dr. S. H. Haughton (Geological Survey, Cape Town). Dr. Andreae is a keen collector of beetles and also a keen mountaineer ; with him I have discussed the possible food-plants of the larva. With Dr. Haughton I have discussed the geological and topographical aspects of the distribution of the genus. Further, I am deeply indebted to several members of the Mountain Club of South Africa with whom I have been out on expeditions and who have helped me in the search for these beetles, namely, Messrs. K. Cameron, A. D. Izard, H. A. Liddle, A. T. Prentice, R. Primos, T. P. Stokoe, and K. White.

Descriptions of Species.

The genus was first described by Gray in 1832, and by Westwood in 1834, the latter giving fuller generic details. The first species was *C. westwoodi* Gray, 1832. In 1855 Westwood added the species *C. thunbergi.*

In 1901 Péringuey (*loc. cit.*, *infra*) united these two species as being the two sexes of one species. It is impossible to say how he reached this conclusion, because, although his descriptions (based on material in the S. African Museum) of the ♂ and ♀ are correct for the two sexes of *westwoodi*, neither corresponds in the least with Westwood's description and figure of *thunbergi* (*cf.* also Boileau, *loc. cit.*, *infra*). In fact, *westwoodi* and *thunbergi* are two perfectly distinct species and have always been regarded as such. I have personally examined the types of both species.

Five new species are here added to the genus. Although I do not approve of the deriving of specific names from personal names as a principle, I feel that I owe so much to my mountaineering friends that I propose that the new species shall bear their names, and thus follow in line with the naming of the two early species of the genus.

In the males well-marked specific characters are found in the mandibles, front tibiae, mentum, and genitalia ; to a lesser extent also in the sculpture of the head, shape of postero-lateral angle of thorax, and sculpture of elytra. The females are distinguished with difficulty, if at all, one from another, and for purposes of distribution isolated females are quite useless.

Colophon Gray.

1832. Gray, in Griffith's Anim. Kingd. Insect., i, p. 533.
1834. Westwood, Ann. Sci. Nat., ser. 2, i, p. 113.
1864. Parry, Tr. Ent. Soc. Lond., 3rd ser., ii, p. 7 (placed in *Chiasognathidae*).
1901. Péringuey, Tr. S. Afr. Philos. Soc., xii, p. 2.
1910. van Roon, Coleopt. Catal., pars. 8, p. 8 (placed in *Chiasognathinae*).
1924. Handlirsch, in Schröder, Handb. Entom., iii, p. 695 (placed in *Lamprimini*).

Péringuey's generic diagnosis must be slightly modified, *e.g.* the quadridentate character of the anterior tibiae is only a specific character. Mentum in ♂ flat, or thickened and strongly projecting; in ♀ always flat. Both sexes wingless, the elytra fused.

Colophon westwoodi Gray.

(Text-fig. 1.)

1832. Gray, *loc. cit.*, p. 533, pl. xlvi, fig. 5 (♂).
1855. Westwood, Tr. Ent. Soc. Lond., n.s., iii, p. 197, pl. x, fig. 1 (details).
1870. Parry, *ibid.*, p. 71 (six specimens known to date).
1901. Péringuey, *loc. cit.*, p. 3, pl. i (31), fig. 1 (♂) (first description of ♀).
1913. Boileau, Tr. Ent. Soc. Lond., p. 218.

Mentum flat, nearly semicircular, strongly foveolate-punctate. Head with lateral margins straight, upper surface in ♂ with a low median tubercle and another on either side of it nearer the anterior margin, an oblique ridge over eye, anterior margin nearly straight; in ♀ anterior margin convex, but with distinct antero-lateral angles, upper surface with low median and lateral ridges, more strongly foveolate-punctate than in ♂. Postero-lateral margin of thorax slightly concave before the sharply quadrate angle. Mandible in ♂ strongly curved, apex bi- (or feebly tri-) dentate, a low rounded prominence on upper surface, at the base a small tooth on upper inner margin, and another on lower inner margin; in ♀ shorter, inner margin bisinuate, apex bluntly pointed, upper surface without tubercle. Front tibia alike in both sexes, strongly 4- (or 5-) dentate on outer margin, the proximal two or three teeth smaller than the two distal ones, and frequently rather variable in development, dorsal surface evenly convex, lower surface concave. ♂ genitalia (see fig. 10, *b*).

*Length.**—♂ and ♀ 19–21 mm. *Breadth.*—♂ and ♀ 10–12 mm.

* The length is reckoned from anterior margin of head to the apex of the elytra; the breadth is the greatest width of the thorax.

Type (♂) in the British Museum. Although the specimen in the Hope Museum, Oxford, is also labelled "type," the British Museum specimen must certainly be regarded as the Holotype (see Parry, *loc. cit.*, 1870).

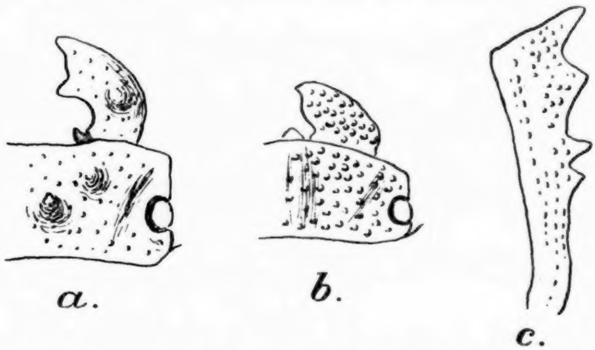


FIG. 1.—*Colophon westwoodi* Gray. *a*, Head and mandible of ♂; *b*, ditto of ♀; *c*, right front tibia of ♂.

Locality.—Cape Peninsula: Table Mountain, Devil's Peak, Constantia Berg, Kalk Bay Mountain; 2000–3500 ft.

Colophon thunbergi Westw.

(Text-fig. 2.)

1855. Westwood, Tr. Entom. Soc. Lond., n.s., iii, p. 198, pl. x, fig. 2 (♂ with details).

1870. Parry, *ibid.*, p. 71.

1872. *Id.*, *ibid.*, p. 83.

1913. Boileau, *ibid.*, p. 217.

Mentum flat, sub-semicircular, sparsely punctate. Head with lateral margins straight, upper surface with a tubercle on either side near inner base of mandible and a transversely oval impression * between the eyes, an oblique ridge over the eye, anterior margin arcuate, surface strongly foveolate-punctate. Postero-lateral angles of thorax obsolete. Mandible strongly falcate, the straight inner lower margin produced as a tooth, another tooth on inner upper margin near base. Front tibia curved, apex strongly spatulate, with two teeth on outer margin, dorsal surface keeled, ventral surface concave. Female unknown.

Type (♂) in Hope Museum, Oxford.

* This is really not a specific character, as all the species have a more or less distinct transverse impression on the back of the head.

Exact locality unknown. No specimens in South African Museum.

Parry (1872) stated that he had added a specimen of this species to his collection, but did not state the source whence he obtained it.

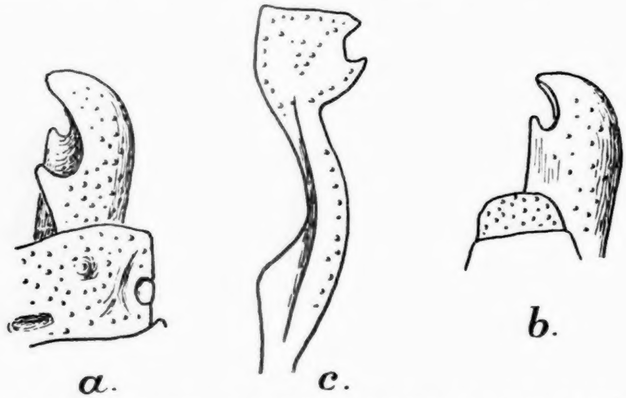


FIG. 2.—*Colophon thunbergi* Westw. *a*, Head and mandible of ♂ ; *b*, ditto, with mentum, lower surface ; *c*, right front tibia of ♂. (From the type at Oxford.)

Westwood's figure shows the mentum far too convex in front; the mentum is really not so semicircular as that of *westwoodi*, being slightly though distinctly flattened in front.

Colophon stokoei n. sp.

(Text-figs. 3 and 4, *a*, *b*.)

Mentum projecting very prominently in lateral view, transversely quadrangular or trapezoidal in ventral view, foveolate-punctate, oblong-ovoid in front view, frontal surface in one specimen distinctly bi-impressed, in the other uni-impressed, punctate. Head with lateral margins straight, upper surface with a compressed tubercle on either side at base of mandible and an oblique ridge over eye, anterior margin concave and declivous. Postero-lateral margin of thorax obliquely truncate before the quadrate, but not sharp, angle. Mandible strongly falcate, inner basal margin of lower surface produced as a tooth, apex subacute, slightly impressed on upper surface between outer and inner margins. Front tibia strongly curved, apex externally bidentate, proximal to which is a semicircular excision, dorsal surface convex with blunt median keel, ventral surface also keeled, distally concave, with a short forwardly directed tooth near insertion of tarsus. Female unknown. ♂ genitalia (see fig. 10, *f*).

Length.—20–21 mm. *Breadth.*—11–12 mm.

Locality.—Hottentots Holland Mountains, south of the Somerset Sneeuwkop; 4000–5000 ft. (K. H. Barnard coll., January 1916. Two live ♂♂.)

The following local variations occur:—

var. A.

Distinctly more robust. Head with a more or less definite anterior margin. Mentum quadrangular, uni-impressed in front. Apex of mandible

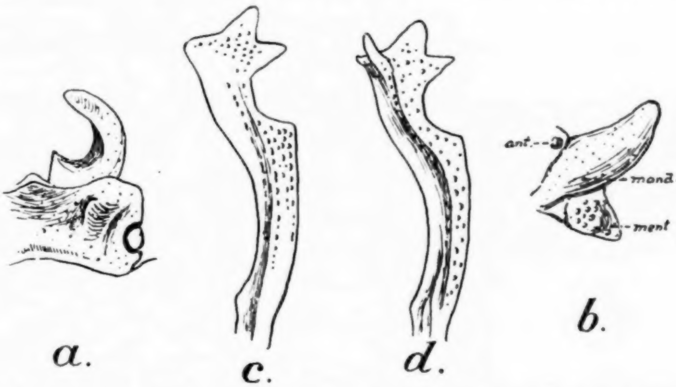


FIG. 3.—*Colophon stokoei* n. sp. *a*, Head and mandible of ♂; *b*, side view of mentum and mandible of ♂; *c*, front tibia of ♂; *d*, ditto, ventral surface.

deeply impressed on upper surface. Front tibia robust. The anterior two-thirds of the margin of each elytron with flattened flange within the costate edge, surface of the flange feebly corrugated transversely. ♂ genitalia as in typical form.

FIG. 4.—*Colophon stokoei* n. sp. *a*, Mentum of type; *b*, of paratype; *c*, of variety from Wellington; *d*, of variety from Drakenstein; *e*, side view of mentum of variety from Drakenstein.

Length.—22 mm. *Breadth.*—13 mm.

Locality.—Hottentots Holland Mountains, southern portion, Kogelberg, 4182 ft. (T. P. Stokoe coll., December 1926, 1 live ♂); and Palmiet River Mountains, 2000–2500 ft. (T. P. Stokoe coll., August 1927, 1 live ♂).

var. B.

(Text-fig. 5, *a.*)

Mentum resembling that of paratype (fig. 4, *b*) of *stokoei* forma typica, sparsely punctate, front uni-impressed. Head with distinct anterior margin (not concave and declivous), with slight median excavation, the excavated portion with a rather well-marked reflexed rim. Front tibia similar to that of the typical form but stouter, the two apical teeth often blunt or even rounded. Apex of mandible strongly impressed on upper surface and more sharply truncate. Female not distinguishable from that of *westwoodi*.

Length.—20 mm. *Breadth.*—11 mm.

Locality.—Palmiet River Mountains, Platberg. (K. H. Barnard coll., February 1927. Dead and dismembered ♂♂ and ♀♀.)

On account of the very distinctive shape of the front of the head, I was inclined to give this form specific rank, until the discovery of the form from the Wellington Mountains.

I have seen a perfect ♂ from the same locality in the private collection of Dr. Andreae, Cape Town.

var. C.

(Text-figs. 4, *d*, *e*; 5, *b*.)

Mentum with anterior margin rounded, ventral surface deeply impressed on either side of a projecting median ridge. Head declivous in front, but

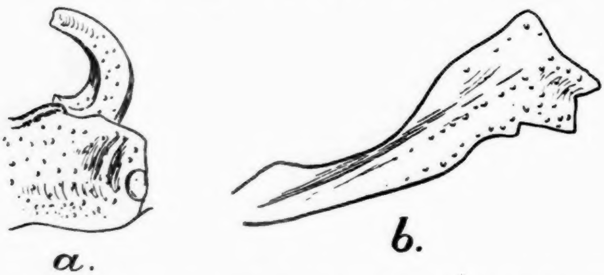


FIG. 5.—*Colophon stokoei* n. sp. *a*, Head and mandible of ♂ of variety from Palmiet River Mts.; *b*, front tibia of ♂ of variety from Drakenstein.

with a feeble indication of a definite anterior margin. Apex of mandible deeply impressed on upper surface. Front tibia with a small third tooth proximal to the two large distal ones. ♂ genitalia as in typical form.

Length.—20·5 mm. *Breadth.*—11·5 mm.

Locality.—Drakenstein Mountains (Stellenbosch District); 4000 ft. (K. H. Barnard and T. P. Stokoe coll., January 1920. One live ♂.)

A ♀ from the outlying mountain Helderberg may belong to this form or to the typical form.

var. D.

(Text-fig. 4, *c.*)

Mentum similar to that of var. C, but with two projecting ridges, causing it to appear distinctly bifid in front in ventral view. Head with a distinct anterior margin which is concave with a slight median point, a strong oblique ridge over eye. Mandible as in typical form, but with the tooth on inner basal margin rounded and nearly obsolete; apex strongly impressed. Front tibia similar to typical form but stouter and less curved, the two apical teeth blunter and the excision less deep.

Locality.—Wellington Mountains, Upper Sneeuwkop; 4500–5000 ft. (K. H. Barnard and R. Primos coll., January 1926. Dismembered parts of ♂ and ♀.)

Colophon haughtoni n. sp.

(Text-fig. 6.)

Mentum flat, semicircular, punctate. Head with lateral margin noticeably expanded in front of eye, surface with broad oblique ridge over eye,

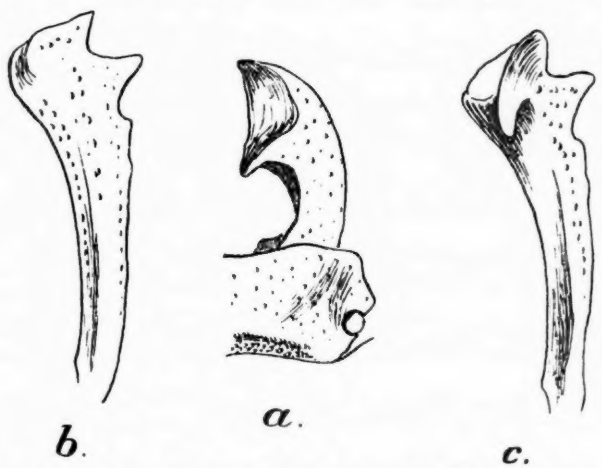


FIG. 6.—*Colophon haughtoni* n. sp. *a*, Head and mandible of ♂; *b*, front tibia of ♂; *c*, ditto, ventral surface.

anterior margin feebly sinuate. Postero-lateral margin of thorax obliquely rounded, the angle obsolete. Mandibles large, shaped like a pair of cutting nippers, the cutting edge subvertical and slightly concave, basal tooth on lower inner margin small, blunt. Front tibia not strongly curved, apex bidentate with a small tooth proximal to the others, upper surface convex, bluntly keeled proximally, lower surface strongly keeled in proximal half, distally concave, with a strong, proximally curved tooth near insertion of tarsus. Middle and hind tibiae with 1 or 2 small spines proximal and in addition to the usual large one in the middle of the outer margin. Female unknown. ♂ genitalia (see fig. 10, *g*).

Length.—20 mm. *Breadth.*—12 mm.

Locality.—Hex River Mountains, Matroosberg; 6900 ft. (S. H. Haughton coll., January 1917. One live ♂.)

Colophon cameroni n. sp.

(Text-fig. 7.)

Mentum flat, more transversely oblong than semicircular, punctate. Head with lateral margin slightly expanded in front of eye, upper surface in ♂ with a very faint tubercle and oblique ridge on either side (exaggerated

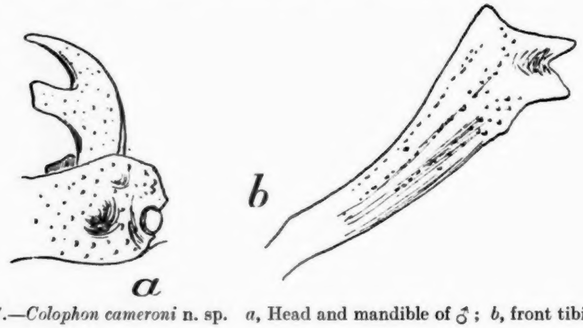


FIG. 7.—*Colophon cameroni* n. sp. *a*, Head and mandible of ♂; *b*, front tibia of ♂.

in figure), anterior margin sinuate; in ♀ with a more or less pronounced median tubercle, strongly foveolate, anterior margin nearly semicircular. Postero-lateral margin of thorax obliquely rounded, angle obsolete. Mandible in ♂ rather elongate, falcate, the inner margin produced in the middle as a square tooth, lower inner margin at base forming an obliquely truncate flange; in ♀ shorter, inner margin bisinuate, apex bluntly pointed, upper surface strongly foveolate-punctate. Front tibia in ♂ apically bidentate, with a small tooth proximal to the others, upper surface convex, lower surface strongly keeled proximally, distally rather flattened but not concave

except below the two apical teeth, with a short somewhat forwardly directed tooth near insertion of tarsus; in ♀ similar to that of *westwoodi*, gradually expanding distally where there are 2 large teeth followed by 1–2 smaller ones. Middle and hind tibiae in ♂ with 1–2 small spines in addition to the usual large one. ♂ genitalia (see fig. 10, *e*).

Length.—♂ 20 mm.; ♀ 17 mm. *Breadth.*—♂ 12–13 mm.; ♀ 9 mm.

Locality.—Waaihoek Mountains (Goudini Road *), top of Waaihoek Kloof and Zebasberg; 5000–5600 ft. (K. H. Barnard coll., January 1925, 1 live ♂; and April 1928, dead ♂♂, ♀♀, and dismembered parts.) Fonteintjesberg (Worcester); 6500 ft. (K. H. Barnard coll., March 1929, dead ♂♂ and ♀♀, parts.)

Colophon izardi n. sp.

(Text-fig. 8.)

Mentum flat, nearly semicircular or somewhat transversely oblong, somewhat sparsely punctate in ♂, strongly foveolate-punctate in ♀. Head with lateral margins straight, upper surface in ♂ with a rather prominent

a *b*

Fig. 8.—*Colophon izardi* n. sp. *a*, Head and mandible of ♂; *b*, front tibia of ♂.

oblique ridge over eye, anteriorly declivous; in ♀ with an oblique ridge over eye, anterior margin convex, more strongly foveolate-punctate than in ♂. Postero-lateral margin of thorax obliquely rounded, angle obsolete. Mandible in ♂ very massive, spatulate or shovel-like, concave inwardly, the lower margin straight, the upper margin concave, the upper front angle sharply pointed; in ♀ shorter, inner margin bisinuate, apex bluntly pointed, upper surface strongly punctate. Front tibia in ♂ slender, distally abruptly bent into an S shape, apex externally produced to an obscurely bifid point, dorsal surface keeled, ventral surface strongly keeled especially where the bend occurs; in ♀ similar to that of *westwoodi*, gradually expanding distally

* See footnote, p. 180.

where there are 2 strong teeth, followed proximally by 2–4 small ones. Elytral flange in ♂ fairly well marked, but only very feebly corrugate. ♂ genitalia (see fig. 10, *d*).

Length.—♂ 22 mm.; ♀ 17·5–20 mm. *Breadth.*—♂ 13 mm.; ♀ 9–11 mm.

Locality.—Langeberg Range, Zuurbrak Peak and Tradouw Peak (Swellendam district), Lemoenshoek Peak (Heidelberg district), and Kampsche Berg (Riversdale district). (K. H. Barnard and R. Primos coll., October 1925, 1 live ♀, and dismembered parts. K. H. Barnard and A. D. Izard coll., November 1927, 1 live ♀, 1 perfect dead ♂, and parts. K. H. Barnard and A. D. Izard coll., October 1926, dead and dismembered specimens.)

This species is characterised by the massive mandibles and the extraordinarily crooked front tibiae of the male. I have taken the types from the Lemoenshoek series as it contains a perfect ♂. All the four complete specimens in this series (live and dead specimens) have a pair of distinct though not sharply defined castaneous spots on the thorax. These spots are entirely absent from the live ♀ from Zuurbrak, and all dead specimens from Tradouw and Riversdale. Lemoenshoek is an intermediate locality on the range between Tradouw and Riversdale. This is the only case of coloration in the genus, excepting possibly *primosi* (*q.v.*).

Colophon sp. incert.

One ♂ head with mandibles, found along with eight heads and front tibiae of the previous species on one of the Riversdale peaks, deserves mention, though in the absence of a front tibia I refrain from naming it.

The head and mandibles are similar to those of *stokoei*, with the inner basal tooth on lower margin larger than in any specimens of *stokoei* or its varieties which I have seen. Moreover, the mentum is quite flat, semicircular, but with two projecting points in front.

The true interpretation of this specimen is a matter of difficulty, and must wait until more material is available. A ♂ specimen complete with front tibiae is required. If the front tibiae should prove to be similar to those of *izardi*, which is not likely, it might perhaps be regarded as a dimorphic form of *izardi*. Even if not specifically distinct, it is the only known case of two forms being found in the same locality (see p. 181).

Further investigation of the range east of Garcia's Pass is necessary to discover whether another species is not living on the Albertinia-Herbertsdale section of the range.

Colophon primosi n. sp.

(Text-fig. 9.)

Mentum flat, subsemicircular, the anterior margin flattened medianly, feebly foveolate in ♂, strongly in ♀. Head in ♂ with lateral margins straight, but slightly expanded in front of eyes, upper surface with slight oblique ridge over eye, anterior margin slightly arcuate and declivous; in ♀ anterior margin from eyes regularly semicircular, upper surface more strongly foveolate than in ♂. Postero-lateral margin of thorax straight, angle rounded. Mandible in ♂ very elongate, as long as median length of thorax, terete, triquetral in cross section, the upper surface flat, the upper and

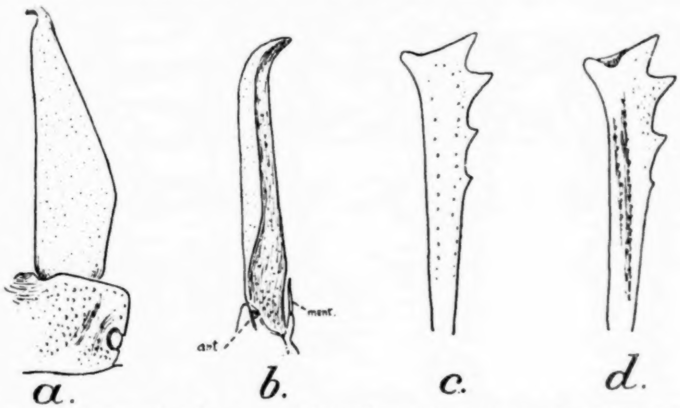


FIG. 9.—*Colophon primosi* n. sp. *a*, Head and mandible of ♂; *b*, ditto, lateral view; *c*, front tibia of ♂; *d*, ditto, ventral view.

lower inner margins straight and apposed to those of the other mandible, outer margin in lateral view sinuate, apex acute, curved downwards and inwards, upper and lower surfaces feebly punctate; in ♀ similar to those of *westwoodi* and the females of other species. Front tibia in ♂ straight, expanding gradually distally, with two large apical teeth, and 1–2 smaller ones proximal to these on outer margin, dorsal surface convex, ventral surface with a double row of small denticles; in ♀ similar to that of *westwoodi*, the two large apical teeth followed by 2–4 smaller ones. Elytral flange in ♂ well marked, with a double row of strong corrugations, margin not costate as in the other species; a well-marked humeral costa extending about one-third length of elytron, and somewhat oblique, crossing the usual fine lines of punctae. ♂ genitalia (see fig. 10, *c*).

Length.—♂ 24–25 mm.; ♀ 19–20 mm. *Breadth.*—♂ 14 mm.; ♀ 11-12 mm. *Length* of ♂ mandible 10 mm.

Locality.—Zwartberg Range, Seven Weeks Poort Berg; 7000 ft. (K. H. Barnard and R. Primos coll., December 1928, 2 dead ♂♂, 2 dead ♀♀, and parts.)

This is the finest and most remarkable of the species hitherto discovered. All four perfect specimens were found on the ground amongst herbage and rocks and had apparently been overcome by a veld fire. One ♂ is black, with the legs and mandibles ferruginous or ochraceous; the other ♂ is dark chestnut, with the legs and mandibles also ochraceous and the lower surface bleached white; of the ♀♀ one is very dark black-brown, the other pale brown, in parts bleached white. The normal colour when alive is certainly black, like all the other species, though possibly the legs and mandibles in the ♂ are paler.

Male Genitalia.

The aedeagus of the male conforms in general with that of *Lucanus cervus* and *Chiasognathus* as described and figured by Sharp and Muir (Trans. Entom. Soc. Lond., 1912, p. 575, pl. xliii, fig. 8), but with certain modifications.

It is enclosed within the barrel-shaped structure composed of the last dorsal and ventral abdominal plates (fig. 10, *a*). The dorsal plate forms a half cylinder and folds over the edges of the spoon-shaped ventral plate. The ventral edges of the dorsal plate show a crease or furrow, which, however, does not extend on to the dorsal surface. On each side the plate is drawn out anteriorly into a stalk. The ventral plate is also drawn out into a stalk anteriorly, and on its posterior broad end is strongly foveolate.

The aedeagus consists of a large basal piece, well developed lateral lobes, and median lobe. The basal piece is membranous and incompletely chitinised on the ventral surface. The lateral lobes are large, broad, twisted; markedly asymmetrical, different in shape in each species. The left lobe is always broader and larger than the right, and often expanded apically into a large triangular or hamate lamina; the right is narrower and apically more or less rounded or truncate. When closed the right lobe folds within the larger left lobe.

The median lobe is about as long as the lateral lobes, tubular, apically obliquely truncate (dorso-laterally), with a few transverse subapical wrinkles. It can be extended on a fulcrum (as in Sharp and Muir's fig. 8 of *Lucanus cervus*), attached to a pair of median struts.

The internal sac is a cylindrical tube, rather longer than the median lobe, permanently evaginated, and passing abruptly into the very long flagellum. When at rest the internal sac is folded down along the ventral side of the median lobe, but somewhat to the right.

The specific differences in the lateral lobes are indicated in the accompanying figure. Three of the species—*westwoodi, primosi, izardi*—show a very strong asymmetry; the asymmetry in the other three is well marked but not so striking.

In *westwoodi* (4 specimens examined), *stokoei* and its vars. A and C (5 specimens), and *primosi* (2 specimens) I have found no individual variations.

Asymmetry of the lateral lobes is not unusual in some Coleopterous families (Sharp and Muir, *loc. cit.*), but in the few examples of the *Lucanidae*

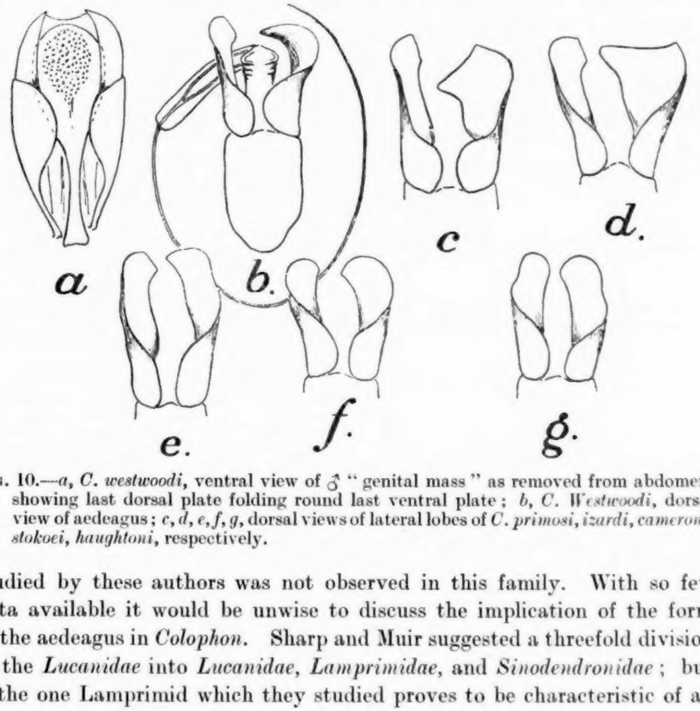


FIG. 10.—*a*, *C. westwoodi*, ventral view of ♂ " genital mass " as removed from abdomen, showing last dorsal plate folding round last ventral plate; *b*, *C. Westwoodi*, dorsal view of aedeagus; *c*, *d*, *e*, *f*, *g*, dorsal views of lateral lobes of *C. primosi*, *izardi*, *cameroni*, *stokoei*, *haughtoni*, respectively.

studied by these authors was not observed in this family. With so few data available it would be unwise to discuss the implication of the form of the aedeagus in *Colophon*. Sharp and Muir suggested a threefold division of the *Lucanidae* into *Lucanidae*, *Lamprimidae*, and *Sinodendronidae*; but if the one Lamprimid which they studied proves to be characteristic of all Lamprimids, then *Colophon* certainly has no affinities in that direction.

VARIATION.

Variation in the *Lucanidae* chiefly affects the male sex, and the extreme forms, known respectively as " high " or teleodont, and " low " or priodont males, are often so dissimilar as to have been referred to different species (*cf.* Leuthner, Trans. Zool. Soc. Lond., xi, p. 385, 1885).

As regards *Colophon* the material is very meagre; I have seen and examined the male heads and mandibles of only 12 *westwoodi*, 18 *izardi*, 26 *cameroni*, and 12, 18, and 7 front tibiae respectively. Nevertheless one may provisionally state that these species are monomorphic; there is no variation in form, only in size.

For example, in *izardi* the breadth of the head varies from 4·5 to 6·5 mm. and the length of the mandibles from 2 to 3 mm. The largest ♀ has a head-breadth of 5 mm. But there is not the slightest approximation in the shape of the smallest ♂ mandibles to that of the ♀ mandibles.

On the other hand, *stokoei* is evidently a plastic species, though its local varieties may prove to be constant or nearly so. The variation in the mentum of the two specimens of the typical form, found within a hundred yards of one another, is interesting. Variation in the mentum is not found in any of the other species.

Habits.

As already mentioned, the people who visit the mountain haunts of these beetles very rarely have the opportunity of spending any length of time at the higher altitudes. A day on Table Mountain, Cape Town, or only an hour or two on some of the more inaccessible peaks, is usually all the time that is available. Consequently not only are these beetles very rare in collections, but also nothing is really known about their habits.

Dr. Andreae tells me that he has found the majority of his live specimens of *westwoodi* on Table Mountain wandering about in misty weather. I have found one ♀ *westwoodi* and one ♀ *izardi* under such conditions. In my experience wandering specimens are mostly found in the early hours of the morning (6–8 A.M.): ♂♂ and ♀♀ *westwoodi*, 2 ♂♂ *stokoei*, 1 ♂ *haughtoni*, 1 ♂ *cameroni*. On the other hand, 1 ♀ *izardi*, 1 ♂ *stokoei* var. C., *stokoei* var. A, were found at midday in hot sun, though amongst low vegetation. One ♂ *westwoodi* I have found under a sheet of corrugated iron near the reservoirs on Table Mountain.

It seems to be indicated, therefore, that *Colophon* is nocturnal and hides by day under or amongst low vegetation. Possibly it burrows also, as suggested by Péringuey (*loc. cit.*, 1901).

As to the time of year, my own and Dr. Andreae's records show that on Table Mountain the beetles appear in mid or late summer from December to March (both of us make frequent ascents of Table Mountain at all seasons of the year). But in some districts the dates of appearance may be somewhat earlier, thus:

2 ♂♂	*stokoei*		Hottentots Holland Mts.	mid January.
1 ♂	,,	var. A,	Kogel Berg	end December.
1 ♂	,,	,,	Palmiet River Mts.	1st August.
1 ♂	,,	var. C,	Drakenstein Mt.	1st January.
1 ♂	*haughtoni*		Hex River Mts.	early January.
1 ♂	*cameroni*		Waaihoek Mts.	,,
1 ♀	*izardi*		Zuurbrak Peak	end October.
1 ♀	,,		Lemoenshoek Peak	end November.

The finding of a specimen on 1st August is noteworthy, and may be explained by the fact that the day was a remarkably hot one for the time of year; the beetle had probably emerged from the pupa, was waiting, as happens in the case of *Lucanus cervus*, for the proper season, and was tempted out prematurely by the unusual warmth.

Although the records are so few, it would seem that December and January are the most likely months in which to search for living specimens.

Regarding the life-history or the food of the larva we have no information. On or near the tops of the mountains where living examples have been found there are at the present day no trees or plants which could be termed woody shrubs, with stems or root-stocks thick enough for larval burrows,* except in one or two places on Table Mountain and Devil's Peak. The vegetation consists of low bushes, mostly species of heath and rushes (*Restionaceae*). In some of the neighbouring kloofs or valleys woody shrubs or even trees do occur, but nowhere in my experience within a distance of at least a mile, and usually much farther away. Moreover, to one who has examined the actual habitats in the field, it seems unreasonable to assume that these flightless beetles could or would wander so far from the food-plants of the larvae.

Dr. Andreae is of opinion that the stems or root-stocks of *Protea* bushes may form the food of the larvae. This may be so in the case of *westwoodi* on Table Mountain or Devil's Peak, but the specimens of *stokoei*, *cameroni*, and *izardi* were found far away from any Protea bushes. In fact, all the specimens found by myself or in my presence have occurred in areas occupied by the Heath-Restio association. It would, in my opinion, be a fair assumption that the larva is a root-feeder, not an internal borer, on one or other of the plants found in this association; and I am inclined to fancy the Restio in preference to other plants.

* It is not to be assumed that the larva *must* be a borer; the larva of *Lucanus cervus* sometimes feeds *on* roots rather than inside them.

Distribution and Topography.

The most interesting feature about the species of this genus is the localised distribution of the several species. Each species is completely isolated on a separate mountain range or massif, or at least is separated by some miles of intervening country intersected with deep gorges. Localities whence specimens are known are few and far between, but future collecting will probably make known other localities.*

The following account of the distribution will be made clear by reference to the accompanying map of the S.W. Cape Province.

The northern part of the Cape Peninsula, culminating in Table Mountain, harbours the species *westwoodi.* It has been found as far south as the Kalk Bay Mountains, but no further south. Just south of Kalk Bay is a broad strip of low-lying land forming a wide gap in the mountain-chain extending across the Peninsula from coast to coast. This has clearly been an insuperable barrier to dispersal for a long time past.

From the mountains on the mainland, where all the other species live, the Cape Peninsula is separated by thirty to forty miles of low-lying country.

C. stokoei and its varieties have been found at a few localities in a long strip of mountainous country from the Palmiet River Mountains in the south to the Wellington Mountains in the north. Although considerably intersected by deep gorges and kloofs, there is only one outstanding low-lying gap or valley throughout the area, namely, the Steenbras River valley separating *stokoei* vars. A and B from the typical form. This valley under present-day conditions forms an impassable barrier. With this exception human beings can traverse the whole area from south to north with only high saddles between the actual rocky peaks or crests, and it would be unwise to say that at the present day the traverse could not be accomplished also by even a flightless beetle. Obviously the whole area has been inhabited by the ancestors of *stokoei* in past times.

Thus the morphology of the beetles and the topography of the country both point to the Hottentots Holland-cum-Drakenstein-cum-Wellington Range as a whole having been isolated from the other mountain massifs prior to its having been divided by deep kloofs into its more or less separate components as we see them to-day.

* It need scarcely be emphasised that collectors should record the exact locality of each specimen, not merely the mountain range but also, if possible, the name of the peak or the nearest peak which has a name. Town names should be avoided. It may be mentioned that one writer (S. Afr. J. Sci., xxv, p. 343, 1928), without any field knowledge of his subject, quotes the locality " Waaihoek Mts." from the specimen in the S. African Museum, and adds " Tulbagh " in brackets. The Waaihoek Mountains are nowhere near Tulbagh.

North of this area there is a wide gap of low-lying country formed by the valley of the Breede River (flowing south-east past Worcester). The north end (Tulbagh) of this valley was once also drained by the same river, but has been tapped by the Berg River on the west, cutting the Tulbagh (Roodesands) poort (gap). This poort is now a barrier between the northernmost part of the Wellington Mountains and the Winterhoek massif, but it has not been a barrier for so long a period as has the valley of the Breede River. It would not be surprising to find on the Winterhoek Mountains a form of *Colophon* allied more or less closely to *stokoei* or its varieties. So far no specimen has been collected on these mountains.

The Winterhoek massif continues southwards (on the east side of Tulbagh) as the Witzenbergen until the deep gorge of Michell's Pass is reached. South-east of this barrier and north of the Breede River valley there is the huge massif of the Waaihoek Mountains-cum-Hex River Mountains.

In the south-west part of this area is found *cameroni*, and in the north-east part the perfectly distinct species *haughtoni*. Some twenty-two miles separate the only localities where these two species have up to the present been found, and there seems to be no physical barrier which would ensure isolation of the two species one from the other. One of the objects of future collecting will be to trace out the distribution of these two species, to find out whether they overlap, and, if not, to try and discover the reasons for their separation.

Separated from the Waaihoek-Hex River massif by the deep though not very broad valley of the Hex River is Keeromsberg, which really forms the westernmost end of the long chain of the Langebergen extending eastwards (under different names) to the Humansdorp district. I have examined only one section of this long range, namely, that in the Swellendam, Heidelberg, and Riversdale districts.

In this section *izardi* occurs. Between the westernmost and easternmost localities there are two deep gorges, Tradouw Pass and Garcia's Pass, which are absolute barriers. There seems no avoiding the conclusion that *izardi* had already evolved its distinctive characters and was in occupation of this area before these two gorges had begun to be cut through the range.

Possibly a similar state of affairs will be found in the Zwartberg Range, but at present the species *primosi* has been found in only one locality, on the west of the Seven Weeks Poort which also cuts right through the range. Search for the beetle should be made on the east side of the poort, and also further east on either side of Meiring's Poort.

Summarising the above account of the distribution, the main point to observe is that all the species are completely isolated from each other, with the exception of *haughtoni* and *cameroni*, and of *izardi* and the " species

incerta " mentioned on p. 174. There are thus five distinct areas, and they are separated by valleys or stretches of country of great geological age. Of what age, and whether of the same age, are interesting questions which local geologists are attempting to solve. Even now there is some evidence to show that some of the gorges and passes referred to above (*e.g.* in the Zwartbergen) may owe their origin or their accentuation to an Eocene-Pliocene uplift. If this be confirmed it means that the genus *Colophon* is of considerable antiquity.

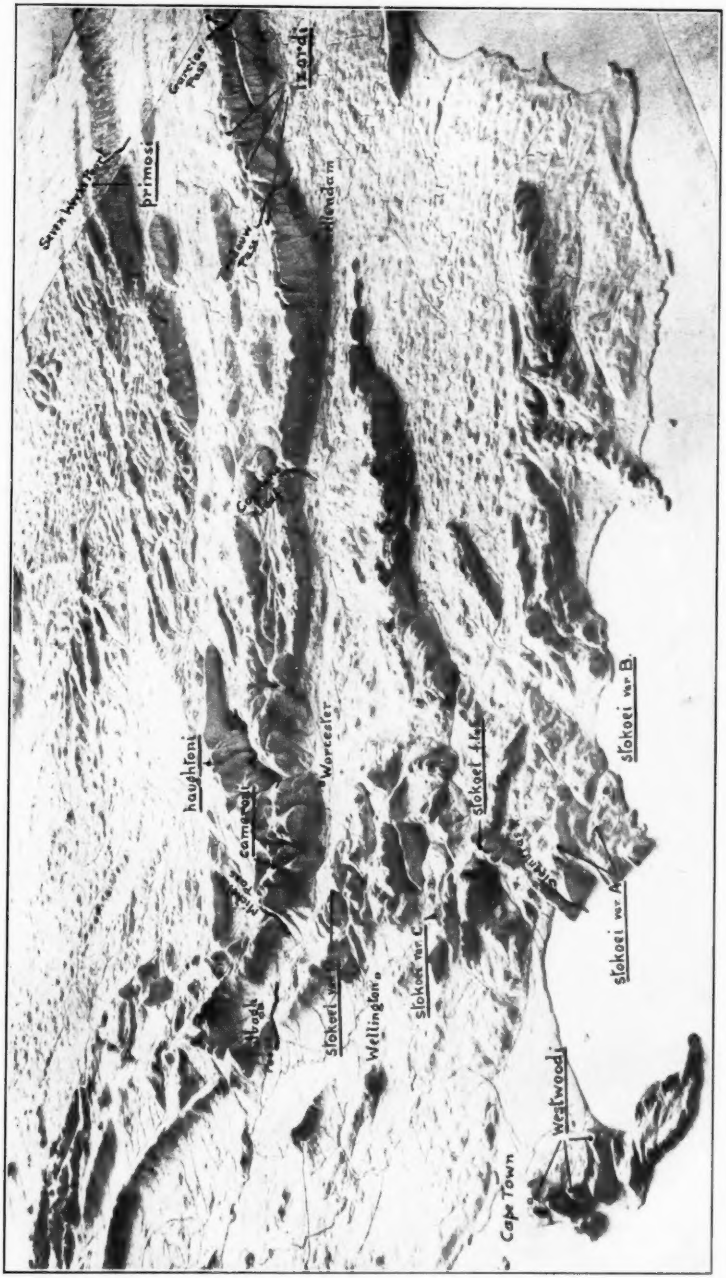
Orogenic movements have been in course of operation in this part of South Africa from Triassic times, and marine transgressions have not been extensive, leaving abundant areas for colonisation by the ancestors of *Colophon*. Where these ancestors came from we have no means of even guessing, nor when they evolved into the flightless *Colophon*. We may, however, assume that, as a flightless form, it was widely spread over the S.W. Cape districts before denudation had proceeded very far in the formation of the isolated mountain ranges we see to-day.

One point of wider significance emerges, namely, the contrast between the insect *Colophon* and the fresh-water Crustacean *Phreatoicus* as regards their past history and the nature of the problems to be investigated, though in both cases we are in the end driven to call in the aid of the geologist.

Phreatoicus is a very constant type and is found, *e.g.*, on Table Mountain, the Hottentots Holland Mountains, and the Swellendam Mountains, with only minor variations. From these same three localities we have three very distinct species of *Colophon*. In the Swellendam-Riversdale area the presence of deep gorges between the various colonies of *Phreatoicus* has no significance, whereas in the case of *Colophon izardi* it raises very important questions. Determination of the age of these gorges, as already hinted at above, would go far towards solving the question of the age of *Colophon*.

EXPLANATION OF PLATE.

Bird's-eye view of relief model of the south-west portion of the Cape Province (in the South African Museum). (Vertical scale four times the horizontal.) Names of the species of *Colophon* underlined.



MAP OF S.W. CAPE PROVINCE TO ILLUSTRATE DISTRIBUTION OF *COLOPHON*.

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COLOUR AND CHEMICAL CONSTITUTION.

PART XXVI.—(A) THE PIGMENTS OF YELLOW FLOWERS; (B) ADDENDA TO PREVIOUS PARTS.

By JAMES MOIR.

A. In Part XXIII, which dealt with the anthocyanidines or high-coloured plant pigments, I mentioned the well-known fact that the low-coloured (yellow and orange) pigments are oxidation-products of the former, being derived from flavone instead of flavylium (see formulae and theoretical discussion there).

When I was in England last year Professor A. G. Perkins very kindly presented me with specimens of the higher members of the flavone family to examine. The results are given below, and also include a few others made by the standard syntheses.

TABLE I.

Name.	Hydroxyl substitutions.	Absorption in conc. H_2SO_4.	Absorption in $NaOH+Na_2SO_3$.	Absorption at about pH5.	Absorption at about pH9.
Flavone	Nil.	340; 385 faint	Nil.	Alcohol 286;	320 and 247 faint.
3-Flavonol	3	350; 390 faint	347	?	as NaOH.
4′-Flavonol	4′	370	340	about 290	as NaOH.
Resoapigenine	7 : 4′	390	about 380	?	
Chrysine	5 : 7	?	..	Alcohol 286,	same as flavone.
Galangine	3 : 5 : 7	about 370	?	Alcohol about 370.	
Resokaempferol	3 : 7 : 4′	?	?	?	
Apigenine	5 : 7 : 4′	406	387 broad	340 broad, 286	as NaOH.
Kaempferol	3 : 5 : 7 : 4′	420	427 very broad	370	370+427.
Fisetine	3 : 7 : 3′ : 4′	405	410 broad	350	as NaOH.
Luteoline	5 : 7 : 3′ : 4′	389	397, 455 faint	352, 286	397.
Quercetine	3 : 5 : 7 : 3′ : 4′	434	429, 460 faint	374	413 broad, strong.
Morine	3 : 5 : 7 : 2′ : 4′	405	410, 438 faint	350	401 broad.
Myricetine	3 : 5 : 7 : 3′ : 4′ : 5′	436 broad	430 very broad	377	as NaOH.
Quercetagetine	3 : 5 : 6 : 7 : 3′ : 4′	432 broad	410, 460, 490 faint	370	410 broad.
Gossypetine	3 : 5 : 7 : 8 : 3′ : 4′	442 broad	about 490 (decomposes)	390	about 440.
Quercitrine	3-rhamroside of quercetine.	422	396, 438 faint	355	396 very broad.

TABLE II.

OBSERVATIONS ON NON-FLAVONE YELLOW PIGMENTS.

Name.	Nature.	H_2SO_4 absorption.	Alkali absorption.
Genistrin .	Kaempferol minus CH of ring	355 non-fluorescent	368.
Maclurin .	2 : 4 : 6 : 3′ : 4′ pentahydroxybenzophenone	318, 395 faint	380.

Flavylium sulphate, which has λ 392 in acid water (Part XXIII), has a higher colour (λ 413) in conc. H_2SO_4. 6 : hydroxycyanidine from reduction of quercetagetine has λ 540 in acid water, and 6 : hydroxyluteolinidine has λ 503. The correct values for luteolinidine are λ 500 in acid water and λ 570 in alkaline. The value λ 486 given in Part XXIII really belongs to the further-reduced substance 7 : 3′ : 4′ trihydroxyflavylium chloride. Gossypetinidine (8 : hydroxycyanidine) is purple in acid water, λ 568 broad, the highest of the series. Gossypetone has λ 500 in acid and about λ 680 in ammonia.

The flavone results appear to show that the effect of each hydroxyl in raising the colour is much the same until the complexity of quercetine is reached, and is thereafter small. The data may be of analytical use, even if their theoretical value is disappointing.

B. (1) *Loading Effect of Methoxyl-substitution in Aurine.*

The results are interesting because the methoxyl group has the greatest bathochromic effect of the simple groups.

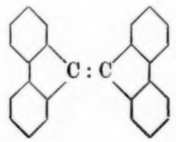
TABLE III.

Name.	Central λ in Alkali.
Aurine	534 narrow.
3 : monomethoxyaurine	551 (ammonia), 543 broad (caustic alkali).
3 : 3′ : dimethoxyaurine	570 broad.
3 : 3′ : 3″ : trimethoxyaurine	584 narrow.
3 : 3′ : 3″ : 5 : 5′ : pentamethoxyaurine	617.
3 : 3′ : 3″ : 5 : 5′ : 5″ hexamethoxyaurine (Eupittone) .	632 broad.

There is thus a rise of nearly 100 units in six nearly equal steps. The substances were made from vanilline, guaiacol, and pyrogallol-1 : 3 : dimethylether by the zinc-chloride method, afterwards oxidizing in alcohol with chloranil.

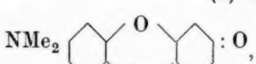
(2) *The Red Hydrocarbon bis-diphenylene-ethylene.*

This is

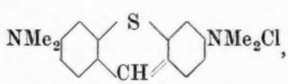


Its absorption-band in ether, alcohol, or chloroform is the same, λ 466 broad. In carbon-disulphide it has two bands, λ 460 broad and λ 496 narrow, thus resembling a xanthophyll. It is very nearly insoluble in cold conc. H_2SO_4, but shows λ 502.

(3) *Xanthenyl Compounds.*



, intermediate between dihydroxyxanthhydrol and pyronine, has λ 510 in alkali, with little fluorescence; λ 552 when acidic; and λ 563 (plus 518 faint) when acid, with a magnificent red-orange fluorescence. Dihydroxyxanthhydrol itself (from resorcaldehyde and resorcinol without condensing agent) has λ 487 in alkali with a very strong *green* fluorescence (slight correction of Part XIV, p. 68). Pyronine has λ 548 (plus 505 faint), with a very intense orange fluorescence. It is remarkable that the intermediate substance has not intermediate properties. In *strong* acid, pyronine has λ 487, non-fluorescent. Monohydroxyxanthhydrol, from resorcaldehyde and phenol, has the unexpectedly high λ 493, with fluorescence.

Thiopyronine,


, is purplish and has λ 568 (plus 524 faint). In dilute HCl λλ 574, 532, 502 : in conc. H_2SO_4 orange λ 469 (plus 502 faint). These changes are due to the sulphur as well as the nitrogens becoming salt-forming.

(4) *Furfurane Colours.*

Furile, C_4H_3O . CO . CO . C_4H_3O (α-α-junction), is yellow in acetone solution (λ 390), and orange in conc. H_2SO_4 (λ 470 broad).

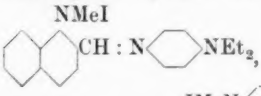
Furoin, C_4H_3O . CO . CH(OH) . C_4H_3O, is dirty-blue in caustic soda solution : λλ 627, 575, and 530 faint. It is olive in conc. H_2SO_4 : λλ 715 and 645. Very few narrow bands are known so high as this.

(5) *Quinoline-cyanine Colours.*

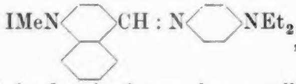
4′ : Dimethylaminostyryl-4 : quinolinemethiodide is purple in dilute alcohol (insoluble in water), λλ 568 and 495. This substance is dimethylamino-benzylidene-lepidine methiodide. The isomeric substance discovered by Hamer, dimethylaminobenxylidenequinaldine methiodide, has λ 532 and is rose. The corresponding pyridine analogue is orange, with λ 465. 4′ : dimethylaminostyryl-4 : quinoline in dilute acetic acid has λλ 550 and 492 (both broad).

Although the β-position in quinoline is unreactive, I apparently succeeded in condensing β-methylquinoline ethiodide with 4 : dimethylaminobenzaldehyde by means of cold conc. NaOH in alcohol. The yellow product, with λ 426, resembles the foregoing compounds in chemical properties, and is presumably 4′ : dimethylaminostyryl-3 : quinoline ethiodide.

Condensing nitrosodiethylaniline with quinaldine methiodide gave a bluish-green cyanine-like substance of λ 620, which is presumably



, an azomethine. Similarly from lepidine methiodide the isomer



, emerald-green, λ 659 (plus 634 faint) was obtained : the former has a yellow, and the latter a brick-red fluorescence in solution. The rise in colour with change from α to γ position is similar to what it is in the quinoline-cyanines, and the rise of colour due to replacing CH in the chain by N is similar to what occurs in the ordinary azomethines as compared with the stilbenes.

It should be noted that it is theoretically possible to make quinoline-cyanines in which the attachment is through the 5 : and 7 : positions, by applying the known processes to 5 : and 7 : methylquinoline methiodides as well as to quinaldine and lepidine methiodides ; also cyanine-like substances from Me_2N⟨ ⟩CHO and Me_2N⟨ ⟩NO and 5 : and 7 : methyquinoline methiodides would probably be easy to make, as would also even 5 : 5′, 5 : 7′, and 7 : 7′ carbocyanines by Hamer's process.

(6) *Loading-effect of Methoxyl-substitution in Phthaleins.*

3 : 3′ dimethoxyphenolphthalein is blue in alkali (λ 599).

3 : 5 dimethoxyphenolphthalein is practically the same (λ 600).

3 : 5 : 3′ : 5′ tetramethoxyphenolphthalein is green in alkali (λ 636).

The first pair of methoxyls raises the colour by 45 units, and the second pair by 37 units more, so that one ring is about five-fourths as

susceptible to the effects of loading as the other (see Part I, end, and Part XXI).

3 : 5 : 3′ : 5′ tetramethoxyphenolsulphophthalein from pyrogallol 1 : 3 dimethylether and sulphobenzoic anhydride without any condensing agent is deep-green in alkali (λ 647). It has λ 489 in acid and λ 420 in conc. H_2SO_4. The total rise on phenolsulphophthalein is 84 units, exactly the same as in the above case.

(7) *C-Ethyl phenolphthaleins (comparison with Cresolphthaleins).*

(1) 3 : ethyl-*p*-*p*-phenolphthalein has λ 565 (λ 571 in alcoholic alkali).

(2) 3 : 3′ diethyl-*p*-*p*-phenolphthalein has λ 578 in alkali.

(3) 5 : ethyl-*o*-*p*-phenolphthalein (from *p*-ethylphenol) has λ 564 in alkali.

The ethyl effect is nearer to that of isopropyl than to that of methyl.

(8) *Miscellaneous Observations.*

(*a*) Dinitrophenthiazine oxide (Schryver's tin test) is blood-red in alkali, λ 490 broad.

(*b*) Erythroapocyanine has $\lambda\lambda$ 490 and 525 coalesced (Mills, J.C.S., 1928).

(*c*) Xanthoapocyanine has $\lambda\lambda$ 450 and 480 coalesced. Bloch and Hamer (Phot. Jl., Jan. 1928) show these bands as single broad ones in the same place.

(*d*) Nitrosoindol nitrate, the product of HNO_2 on indol (HNO_2 test), has $\lambda\lambda$ 520 and 490.

(*e*) 4′ : nitro-3 : ethyl-4 : hydroxyazobenzene has λ 502 broad in alkaline water, λ 535 in alcoholic alkali, and λ 580 in presence of a trace of magnesia.

(*f*) 4′ : nitro-5 ethyl-2 : hydroxyazobenzene is nearly insoluble in alkaline water, λ 560 : λ 580 in alcoholic alkali.

(9) *Further Studies on conc. H_2SO_4 as Solvent.*

Alizarine in aqueous alkali has $\lambda\lambda$ 612, 560, 266 ($\nu\nu$ as 20 : 22 : 46). Alizarine in H_2SO_4 has $\lambda\lambda$ 625, 500, 320, 272 ($\nu\nu$ as 20 : 25 : 39 : 46). This is quite a remarkable result. The ratio of corresponding bands is 0·979.

The corresponding ratio (H_2SO_4/NaOH) is 0·975 in 2 : hydroxyanthraquinone.

Anthracene-1: sulphonic acid has five harmonic bands in both solvents ($\nu\nu$ as 33 : 35 : 37 : 39 : 41), and the ratio is 0·968.

Apparently the ratio is constantly 0·97 when no chemical action takes place.

Quinizarine in aqueous alkali has $\lambda\lambda$ 606 and 559 ($\nu\nu$ as 12 : 13). Quini-

zarine in H_2SO_4 has $\lambda\lambda$ 548, 505, 326, 262 ($\nu\nu$ as 12 : 13 : 20 : 25). The effect is *in the opposite direction*, and the ratio is 1·107.

α-anthrol has bands with $\nu\nu$ ratio 9 : 10 in both solvents, and the acid/alkali ratio is 1·14.

In the inorganic field there are some remarkable results. Uranyl bisulphate in conc. H_2SO_4 has nine bands—centre strongest—given by: $\nu=23610\pm790\ n$, where n is 0, 1, 2, 3, 4, whereas in water the top band is strongest and the equation is $\nu=21130+662\ n$.

Permanganic acid gives the surprising effect of a greenish solution in conc. H_2SO_4, exhibiting the bands $\lambda\lambda$ 730, 700, 675, 490, 470, 450. In water the bands are $\lambda\lambda$ 572, 546, 524, 503, etc. The ratio is a double one and equals $\frac{7}{6}$ and $\frac{7}{9}$, which is very remarkable.

Neodymium in conc. H_2SO_4 is, however, little different from its water solution ($\lambda\lambda$ 578 and 572 respectively); ratio 0·99. Tetravalent uranium has $\lambda\lambda$ 666 and 650 respectively; ratio 0·976.

The $\frac{7}{6}$ and $(\frac{7}{6}\times\frac{2}{3})$ ratios for $HMnO_4$ seem simple enough to lead to a physical explanation.

THE VOLCANIC BELT OF THE LEBOMBO—A REGION OF TENSION.

By Alex. L. du Toit, D.Sc., F.G.S.

(With Plate II and four Text-figures.)

CONTENTS.

I. Introduction.

The eastern boundary of the Transvaal, Swaziland, and Northern Zululand is constituted by the striking, although not very lofty, Lebombo Range. Shutting off the interior region from the coastal plain, this important feature runs due north and south for 500 kilometres with the utmost regularity (Plate II), a fact that alone is sufficient to excite curiosity.

Notwithstanding the undoubted interest of the Lebombo from the geological and geographical standpoints, it has not attracted the attention which it deserves, and not only are papers concerning it surprisingly few, but considerable sections of its length remain wholly unexplored. There is, indeed, no other part of South Africa concerning which so little is known, and a certain amount of glamour accordingly attaches to this barrier, which for the greater part of its length forms the political boundary between the Union and Portuguese East Africa, and is situated far from the centres of civilisation. Much of its western side lies within the Sabi Game Reserve, a

territory infested by lions and elephants, while its eastern slopes are only sparsely inhabited by natives, and are, moreover, not easy of access.

Structurally the Range consists of a regularly tilted *monocline* sloping towards the east, with Karroo Beds, resting on the Archaean, cropping out along its base on the west, followed conformably by basic lavas, these by acid effusions composing the Range proper, and those in turn (when present) by further basic lavas. The whole assemblage sinks in an easterly direction beneath the horizontal Cretaceous, Tertiary, and Quarternary deposits of the Littoral. Fig. 3 is a typical section through this monocline or "cuesta," as geographers would call it.

II. Previous Investigations.

We owe the earliest connected account to Cohen,* who in 1873 travelled from Lydenburg to Delagoa Bay, and crossed the Lebombo near Matalha Poort some 20 kilometres south of Komati Poort. Though very little is said about the structure of the belt, his description contains a wealth of petrological detail and also several important suggestions; for example, that the diabase dykes were probably the feeders of the melaphyres (basalts) (p. 239), and that the quartz-porphyries were probably genetically linked with the latter. He furthermore notes the basalts and felsites of the Little Lebombo (pp. 264–266).

In 1897 Wilson-Moore † briefly described the coal-bearing beds along the Sabi River just north of Komati Poort, and referred incidentally to the "porphyrite" (rhyolite) of the Range, regarding it as an immense dyke. The succeeding year Molengraaff ‡ gave a short account of the Komati Poort area. The easterly dip of the Karroo sediments and volcanics was duly noted, and the strata were considered to form a down-faulted strip of the coal-formation of the "Highveld."

The southern portion, falling within Zululand, was mapped roughly and described briefly by Anderson § in his Reports of 1902 and 1904, work that was continued within Swaziland by Garrard,|| and beyond that and up to the Selati River by Kynaston,¶ their accounts embodying the bulk of our information concerning the inner portion of the belt. The country between Swaziland and Delagoa Bay is known from the researches of Henderson ** and Young †† supplementing the petrological work done by Prior ‡‡ upon specimens submitted from Zululand and Natal.

Northwards from the Sabi lies a stretch quite unknown—save for a casual

* E. Cohen, **2**, pp. 235–266 (see References at end of paper).

† **4**, p. 131. ‡ **5**, pp. 137–139. § **6**, p. 39; **7**, pp. 39–67.

|| **16**, p. 75. ¶ **8**, **9**, and **10**. ** **13**, p. 24.

†† **18**, p. 98. ‡‡ **14**, p. 152.

reference made by Erskine * in 1875 of porphyry (rhyolite) in the poort of the Olifants River—until we reach the Pafuri River and the Limpopo, where Rogers † made detailed observations in the area east of the Zoutpansberg, which were surprising in proving the existence of basalts, limburgites, and nepheline-basalts overlying the Bushveld Sandstone, which is of uppermost Karroo age. Specimens brought back by W. P. Murray, Surveyor-General of the Transvaal, have demonstrated the presence of similar types in the hardly known territory lying between the Pafuri and the Great Shingwedzi Rivers.

The writer's acquaintance with the belt has been restricted to traverses along the Letaba River, Olifants River, along the railway from Tenbosch Station, past Komati Poort to Moamba Station in Portuguese territory, and within the southern part of Swaziland and the northern part of Zululand on several occasions, though but little detailed mapping was possible. The geology is upon such a wonderfully broad scale, however, as to enable more than a mere outline of the geological history of this part of South Africa to be gleaned, and these notes are set down partly because of that reason and partly because the continuation of such investigations has become unlikely.

These scattered observations nevertheless extend our knowledge concerning the late Karroo volcanicity considerably, demonstrate the enormous thickness of the materials erupted, indicate that the earliest effusions were in some places of an unusual basic or alkaline character, and confirm the suspicion, long entertained, that these plateau lavas were erupted primarily from fissures. Furthermore, they show that this monoclinal structure represents the hinge-line of the continent along which the earth's crust was not only flexed but put into considerable tension during the early part of the Jurassic Epoch. Hitherto such warping has tacitly been assumed to have occurred long after the close of the Stormberg volcanicity, but the new data indicate a movement anterior to the well-known mid-Cretaceous orogeny that affected the south and south-east of the Union.

III. Geography.

Previous writers have all pointed out that the topographical feature produced by the Range has been caused by the superior resistance under erosion of the rhyolites. So far as can be gathered, that division only extends for a short distance to the north of the Great Shingwedzi River, the Range commencing there and then running southwards to the Umsinene River in Zululand, a distance of almost five degrees of latitude, following with remarkable fidelity the thirty-second meridian.

* 3, p. 45. † 22, p. 33.

The volcanic zone constituted by the Lower basalts is, however, more persistent, being continued for many kilometres at either end, namely in a heavily bushed but gentle plateau between the Shingwedzi and the Limpopo in the north, and in rather bare, rolling ground with isolated ridges in the Hluhluwe area in the south.

Throughout its length of some 540 kilometres the Lebombo proper displays a wonderful constancy of character, namely, (*a*) on the west an undulating or flat belt composed of basalts, (*b*) a central ridge rising a few hundred metres built of rhyolites, with a westerly facing escarpment, and possessed of a surprisingly even skyline, and (*c*) an eastward slope falling by steps or by means of low foothills towards the coastal plain. This side is situated very

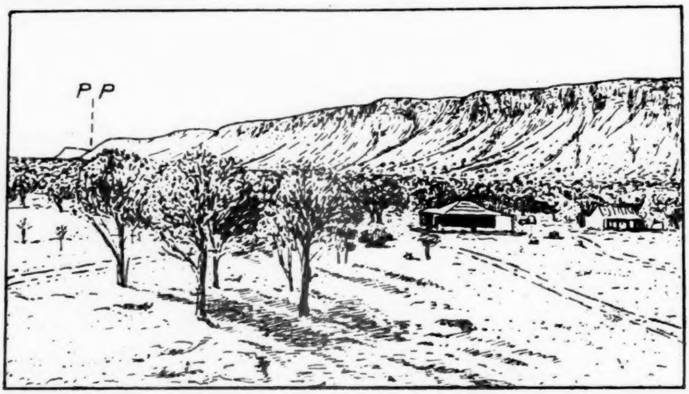


Fig. 1.—The Escarpment of the Lebombo Range, looking northwards from Mkuzi: in foreground the Lebombo Flats; at *PP* the poort of the Pongola River.

largely within Portuguese territory and is hence not well known, but is, from all accounts, more variable scenically than the western one. Of these three zones the first makes flattish bush country or gently rolling ground (Lowveld), standing at between 130 and 200 metres in its southern half, with a rise to about 300 metres in its northern. It includes to the south of Komati Poort important stretches of tree-clad plain covered by dark red soil of excellent quality derived from the decomposition of the underlying basic igneous rocks; these indeed constitute the well-known "Lebombo Flats" (fig. 1).

The crest of the Range itself commonly stands at between 450 and 550 metres above sea-level, but is higher just north of the Olifants River and also at the north-eastern corner of Swaziland, where it culminates in a peak 800 metres high overlooking Namahacha. Its crest is stony, scantily timbered, and rather bare, especially in the south, where it descends rather

rapidly to the coastal plain. Between Namahacha and Lourenço Marques one finds east of the principal chain a lesser range with a maximum elevation of 269 metres known as the Little Lebombo, consisting of a plateau, scarped on its inland side, of basaltic lavas with some rhyolite, dipping gently seawards.

The Coastal Plain stands at under 100 metres above sea-level between the Umfolozi River and Delagoa Bay, after which it rises to between 150 and 200 metres, and exceeds the latter figure north of the Olifants River. In the southern half of this zone, grey, whitish, red, or chocolate-coloured Pleistocene sands, with a fair growth of vegetation, conceal the solid geology. Isolated outcrops of fossiliferous, marine, Cretaceous Beds show themselves along some of the rivers, but towards the north, according to both Elton * and Erskine,† a considerable development is found of red sandstones and of limestones of unknown age.

The *hydrography* displays features of extreme interest (Plate II). The drainage from the interior passes through the Range by means of thirteen eastward-trending, narrow ravines often difficult of negotiation, even on foot, and not only is this the case with the larger rivers having their sources far to the west, but with certain of the lesser streams that arise within the "Lowveld" itself; in the south these gorges are remarkably close together. In spite of the continuous and broad stretch of low ground inside the Range, and the gentle divides between these west-east flowing rivers, tributary streams coursing approximately parallel to the escarpment are always small.

Such physiographical peculiarities are to be explained as being due to the initiation of the main drainage lines upon an extensive erosion surface or peneplain that once bridged the great trough between the "Highveld" of the Eastern Transvaal and the Lebombo, as will be discussed in Section VIII. With uplift of the continent, a gridiron system of west-east "consequent" rivers was developed, that to-day pass through gaps transverse to the Range, while behind the latter a tributary north-south "subsequent" set was developed. The history is hence almost identical with that of the great river systems of the south-east and south of the Union.

IV. The Karroo Sediments.

In the absence of any evidence to the contrary, it may be accepted that on the west sedimentary beds of Karroo age intervene between the crystalline basement and the volcanic rocks along the full length of the monocline. Their detailed stratigraphy nevertheless still remains to be worked out.

In the extreme north Rogers ‡ found a lower group that could with

* 1. † 3. ‡ 22, p. 42.

confidence be ascribed to the Ecca Series (Permian) and an upper one undoubtedly representing the Bushveld Sandstone Series (Trias-Rhaetic). At the Mateolo beacon close to the Letaba River the Karroo sediments form a band only 800 metres wide, are dipping eastwards at about four degrees, and probably do not exceed 40 metres in thickness, when allowance is made for "dyke-faulting" (fig. 2). Resting upon a slightly uneven surface of Archaean rocks come thin, brown, or dark, impure limestones veined by quartz, overlain by hard, pale grits and pebbly, quartzitic sandstones, and these by shales with another band of grits, purplish towards the top, carrying angular grains of felspar, pink or reddish quartz, quartzite, etc. Next follow friable red or maroon clayey sandstones, which pass up into an intensely hard red sandstone breccia traversed by cherty and calcareous veins, overlain by the Bushveld Sandstone, upon which stands the trigonometrical beacon. The rocks immediately below this sandstone are imperfectly described in the above lines, but resemble so remarkably the silicified calcareous breccias of the Kalahari, as to suggest that they may have been formed under semi-arid conditions. The Bushveld Sandstone weathers in the rugged fashion typical of that formation and probably does not exceed 11 metres in thickness. It is fine-grained, unbedded, pale to reddish in colour, with hard, calcareous concretions near its base, but the uppermost few metres are distinctly stratified and redder. Just to the east of the beacon it is overlain by blackish limburgite lavas, the surface of the sandstone being slightly uneven.

While the upper half of this sedimentary succession can definitely be identified with the Bushveld Series (Stormberg), the status of the lower half remains in doubt. Comparison with the remarkably similar lithological succession in Southern Rhodesia nevertheless tempts one to parallel the lower part with the "Escarpment Grits," which immediately underlie the Forest Sandstone (=Bushveld Sandstone), and hence with the Molteno Beds (their presumed equivalent), but fossils would be needed to confirm such a correlation.

In the stream bed to the south of the Mateolo beacon is a particularly clear example of "dyke-faulting," the limburgite-sandstone junction having been duplicated by a strike fault that is occupied by a dolerite dyke trending north-south; the downthrow is 2·5 metres to the west. This is merely one out of a host of similar parallel intrusions that have sliced up the formation, many of which seem to occupy planes of small displacement or "slip-faulting," a feature prevalent throughout the region under consideration, though only occasionally is it possible to detect such movement or to measure its amount.

The observations by Kynaston and Gerrard on the Karroo sediments in the area from Komati Poort southwards through Swaziland have been

reviewed by Wybergh,* who makes it clear that the thickness of strata may exceed 600 metres, a more reliable estimate being impracticable, first, because of the abundance of intrusive dolerite, and, secondly, because of the unknown amount of the dislocations produced by such intrusions. The width of the belt is from 4 to 5·5 kilometres, and the dip consistently eastwards at from 5 to 12 degrees. The lowest beds are shown by their fossils to belong to the Ecca Series, while the uppermost can on lithological grounds be allotted to the Stormberg Series, so that the middle portion—of considerable thickness—could quite well include a part of the Beaufort Series (Permo-Triassic). Just beneath the red Bushveld marls is a relatively thin zone of reddish or white, coarse-grained sandstones like those mentioned at Mateolo resembling the Molteno Beds and Escarpment Grits.

On proceeding towards Zululand, intrusive dolerite becomes more and more abundant, and in the broken country formed by the Rooi Randt next the Pongola River and by the Inhlangdena Hills beyond, the Karroo System—sediments and volcanics alike—has been disrupted and penetrated by basic matter to an extraordinary degree. Over a huge area the sediments constitute probably only about one-fourth of the total in the form of mere strips and patches enveloped by dolerite, yet always dipping regularly eastwards at angles of up to 20 degrees. Not much is known about the stratigraphy of this extensive region, excepting that the Bushveld Sandstone is recognisable in the Rooi Randt, but south of the Umfolozi River the full succession from the Dwka Conglomerate upwards has been discovered, building a monocline with dip ever increasing in a south-easterly direction until the volcanics are found tilted to angles of 50 degrees in their ultimate outcrops near Matubatuba Station. Curiously, however, the amount of dolerite, though large, is about the same as is normally found throughout Natal.

To sum up, the Karroo sediments, when followed from south to north, thin progressively, through the dwindling or disappearance of the middle or lower portions, so far as can be judged ; concurrently the amount of dolerite increases rapidly to a maximum in the Mkuzi-Pongola section, and thereafter diminishes. The earliest strata in the Lebombo are of Lower Permian age, while the Bushveld Sandstone represents the Rhaetic.

V. The Volcanic Rocks.

The belt made by the effusions ranges in width from about 20 up to almost 50 kilometres, and has an unbroken length within the Union of 660 kilometres. Where fully developed there is a triple succession of lavas—basic, acid, basic—with an initial ultrabasic and alkaline facies in

* 23, p. 142.

the north. The maximum thickness can be determined only approximately, but, after making liberal allowances for dyke-faulting, it cannot be less than 9000 metres, while erosion has obviously removed still higher horizons.

A. *The Lower Basalts—including the Limburgites, etc.*

From north-east and east of the Zoutpansberg, Rogers * has described an extensive development of basic basalts, limburgites, and nepheline-basalts intimately associated, that from indirect evidence were taken to be reposing upon a somewhat uneven surface of Bushveld Sandstone, the assemblage being cut by dykes indistinguishable from many of the Karroo dolerites. In view of their unusual petrological characters—being quite unlike the normal Stormberg lavas—but close resemblance to the Cretaceous

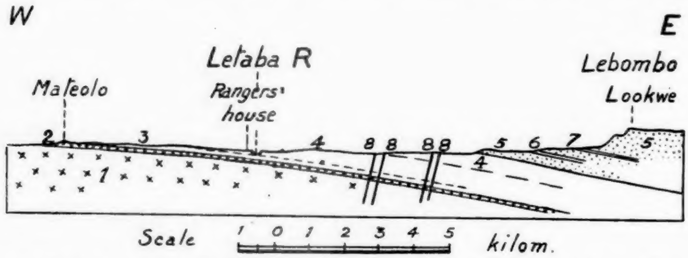


FIG. 2.—Section across Letaba Valley to the Lebombo. 1, Crystalline rocks; 2, Karroo beds; 3, limburgites; 4, basalts; 5, rhyolites; 6, andesite; 7, epidotic lava; 8, 8, felsite dykes. The multitude of dolerite dykes that cut the lower group of volcanics has been omitted.

and Tertiary alkaline volcanics of Moçambique territory, there was some doubt whether the Zoutpansberg rocks were not of similar or at least of post-Karroo age. Direct evidence thereon was unfortunately wanting. Samples of similar volcanics were, moreover, got by Murray between 45 and 55 kilometres south of the Limpopo and some 15 kilometres west of the Portuguese border.

The more complete sequence along the Letaba River decides this point, and shows that a highly basic phase ushers in the normal Stormberg volcanicity within the northern half of the Lebombo, for this ultrabasic zone, though much reduced, has been discovered so far south as Komati Poort, though whether it runs uninterruptedly throughout the entire distance from the Limpopo is not yet known.

In the *Letaba* area the volcanics commence just to the east of the Bushveld Sandstone ridge supporting the Mateolo beacon, and the Lower group crosses the Letaba and reaches to the western foot of the Range, a distance

* 22, pp. 44–53.

of 11 kilometres, the easterly dip increasing in that distance from 3 to nearly 12 degrees (fig. 2); good sections are exposed along the left bank of the river. Uncorrected for the dislocations attendant upon the intrusion of the dykes, the thickness would be only 1200 metres, much less than farther to the south.

Resting upon a slightly uneven surface of Bushveld Sandstone (fig. 2 (2)), and forming a belt about 1·5 kilometres wide, comes a group of black, rather vitreous limburgites associated with basic basalts with some visible felspars (3), though nevertheless more basic than usual, and after them normal basalts and basaltic andesites (4), though what were taken in the field for limburgitic types were noticed to the east of the Letaba on a horizon about one-quarter way up in the succession.

The thin section of the basal flow at Mateolo shows under the microscope partly or wholly serpentinised idiomorphic olivines and augites, also smaller crystals and granules of these minerals, set in an abundant, dense, blackish glass containing plates of iron ores. Felspar is absent and the rock is a typical limburgite. A somewhat higher flow at this spot proved to be a limburgitic basalt with a fair amount of labradorite felspar, some glass, and a good deal of ilmenite. No obviously alkaline types were observed *in situ*, but a pebble gathered from the shingle of the Letaba carried prisms of a dark mineral which proved in the thin section to be a green, slightly pleochroic and conspicuously twinned augite, evidently a soda-bearing variety. Small prisms and granules thereof are abundant in the ground-mass, which, though dusty and full of minute granules, is colourless, and from its optical characters may be nepheline rather than felspar. The numerous amygdales are filled with natrolite. This transported lump, though not agreeing with the description by Rogers * of the nepheline-basalts of the Pafuri area, nevertheless suggests the presence of types with distinct alkaline affinities to the north or north-west of this spot, presumably within the drainage area of the Letaba and hence from ground situated to the south of the Great Shingwedzi River.

The rocks grouped as basalts include most of the types characterising the Stormberg volcanics, and range from dark, crystalline, doleritic kinds to grey, brown, red, or purple amygdaloids. A layer of pipe-amygdaloid is almost invariable at the base of each effusion and is of great value, not only in defining each separate flow, but in enabling the dip of the latter to be determined. Layers of sandstone or tuff are absent. The change from the basalts to the succeeding rhyolites is sharp.

At *Komati Poort* the width of this group is 9 kilometres, but Kynaston † was in error in reporting the dip of the sediments and volcanics to average about 10 degrees. The good sections available along the Stony Spruit

* **22**, pp. 49–51. † 8, pl. ix.

south of the railway show that in the case of the basalts the inclination increases steadily from 10 degrees in the west to 25 in the east, and is much higher still in the rhyolites beyond (fig. 3). A northward-striking dolerite dyke crops out about every 50 or 100 metres, while at the township of Komati Poort the formation is interrupted by a huge intrusion of gabbro-diorite over 1·5 kilometres wide. The depth of the basalts could not exceed 2400 metres and, allowing for dyke-faulting, may perhaps be somewhere about 1600 metres in thickness.

Along the Stony Spruit the formation following immediately upon the Bushveld Sandstone is obscured by soil for about 50 metres, but a boulder of limburgite was picked up in the stream bed at this point, proving that the earliest material erupted was abnormally basic. The thin section shows corroded olivine phenocrysts set in a mass of ragged crystals and granules of augite enclosed in a faint brownish glass having plates of ilmenite giving gridiron patterns ; felspar is absent. The lavas succeeding this basal flow are normal basalts.

At the few points in the southern part of Swaziland and beyond, where it was possible to examine the base—for instance, at Vlak Nek in the Rooi Randt—no limburgite intervened between the Bushveld Sandstone and the basalts, and the succession is hence the normal one. On the Ingwavuma, Pongola, and Mkuzi Rivers the width of the group is 18 kilometres ; dips are high—from 25 to 30 degrees usually—though rising in a certain section to 35 and even 40, while the flows are sliced into narrow strips by dolerite dykes. Fig. 4 is an illuminating section measured along the right bank of the Pongola River near the railway bridge, and demonstrates not only the abundance of such intrusions, but their behaviour in step-faulting the lavas, a feature disclosed by the dislocation of an interbedded pinkish sandstone about half a metre thick. The section, over two-thirds up in the Lower basalts, is located right on the axis of the monocline, and there are reasons for believing that the dyke-faulting attains its maximum here and becomes less to both east and west. Under the circumstances any estimate of the thickness of the basalts involved in this locality would be unreliable.

From the Umkuzi River southwards the basalts and the underlying Karroo beds are riddled by dolerite intrusions, and it becomes difficult from Anderson's account to obtain any clear idea either of the limits of those two groups or of their attitude. Dips are certainly high from the Mkuzi so far at least as Hluhluwe, while the strike of the volcanics changes from N.-S. to N.N.W.-S.S.E. in that distance.

Acid lavas have very occasionally been noticed in this division. Just north of the Ingwavuma River on Mr. Prigge's farm, 16 kilometres west of the Premier Cotton Estates, a fine-grained pale trachyte with orthoclase phenocrysts is sandwiched between basalts not far above the base of that

group ; a second band is seen on the Estates, and also a flow of rhyolite still more to the east, yet fully 2 kilometres west of the escarpment made by the acid rocks.

B. *The Rhyolites.*

Specimens brought back by Mr. Murray from the Union Border, 50 kilometres from the Limpopo, and also from the Shingwedzi beacon include rhyolite or felsite, but the acid lavas, and with them the Range, seemingly commence at the Shingwedzi River. At the junction of the Letaba with the Olifants the acid belt must be many kilometres wide, the formation being reported to continue without change so far at least as the Portuguese border (16 kilometres), though that statement may not be correct. In the rise from the Letaba to the crest of the Range at the Lookwe beacon, a distance of 4·5 kilometres, one meets with red rhyolites dipping eastwards at 12 degrees (fig. 2 (5)), followed by some bluish, coarsely porphyritic andesites (6) (including vesicular varieties) with andesine felspars up to nearly a centimetre across and by a band of blue epidotic lavas (7) higher up in the succeeding rhyolites. The rest of the section consists of red rhyolitic lavas giving rise to bare, stony surfaces, the massive granophyric sheet building the upper part of the Range having a thickness of at least 120 metres as measured from its clearly marked base. Basic dykes are most curiously absent. Not less than 1700 metres of acid lavas must be represented in this section, but as the group stretches far to the east it must undoubtedly be of great thickness.

At *Komati Poort* the belt extends from the entrance to the gorge almost to Chanculo Station, giving a breadth across the strike of

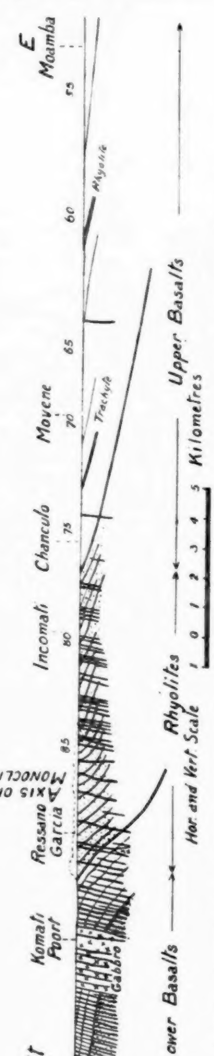


Fig. 3.—Section through the Lebombo at Komati Poort, projected upon an east-west plane. The nearly vertical lines indicate dolerite dykes, which in the extreme western end have to be represented diagrammatically.

10 kilometres (fig. 3). The fine sections along the railway enable the limits of individual flows to be made out in a fair number of instances, thicknesses of from 30 to 60 metres being measurable in certain cases. The rhyolites are reddish or terra-cotta coloured, banded or streaky, compact rocks with small, visible felspars, but are greenish when freshly quarried. They are occasionally amygdaloidal, particularly towards the tops of flows, where the rock may contain druses filled with agate, or may be even highly pumiceous. Glassy types (pitchstone) are rare, while tuffs are almost unrepresented, though both kinds are seemingly not uncommon farther to the south along the Swaziland border (Henderson and Young) and beyond (Prior).

So amazingly high is the dip of the banding—up to 60 degrees—in the section between kilometre posts 85 and 88, as to have led the writer seriously to doubt whether it could indicate the original stratification of the effusions. A careful study of the contacts between successive outpourings proved, however, that such colour or textural banding coincided in the main with the actual dips of the flows. Such banding is extremely consistent, though locally contorted and confused striping can also be found. No undoubted instance of reversal of dip was anywhere noticed. Such irregularities as were seen must in the main have been due to the high viscidity of the erupted material, as indicated by occasional brecciated zones and irregular, slaggy crusts.

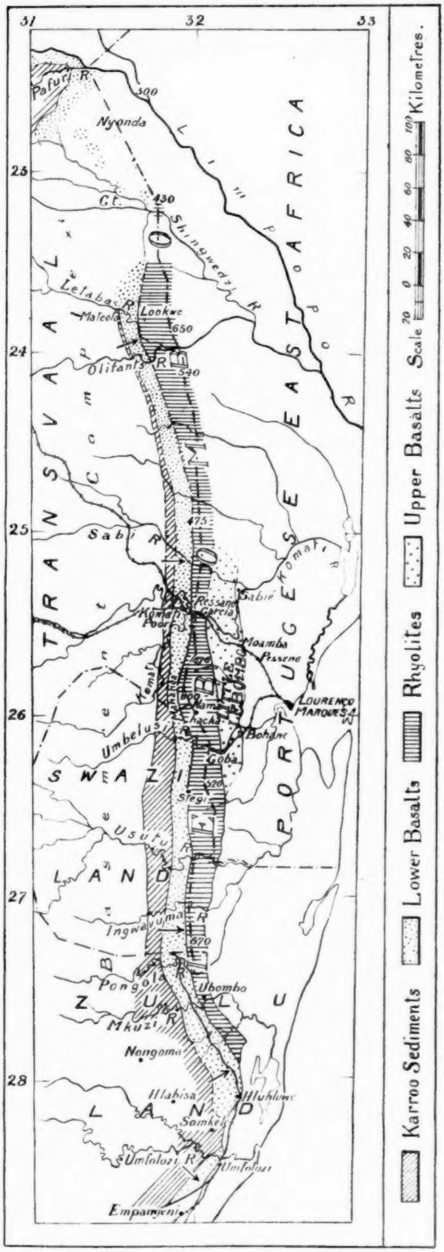
Of interest was the occurrence at kilometre 84·3 of red, deeply oxidised tops to two successive flows.

The section in fig. 3, which was compiled from data of this kind and was plotted on a large scale, gave a thickness for this group of 4800 metres; even allowing for such faulting as might accompany the relatively few dykes, this figure would still be astonishingly large. Of such intrusions a fair number were observed and mapped, the majority inclined at a steep angle to the west.

South of the Komati area the average dip diminishes and the breadth of the belt decreases to a maximum of 25 kilometres, which is attained in the section through Namahacha, the inclination lessening on proceeding eastwards.* Thereafter the width gets smaller, and down to the Umsinene River is generally less than 16 kilometres.

Petrological descriptions and analyses have been given by Cohen, Henderson, Prior, and Young, and it will therefore suffice to state that the effusions range from granophyres—like that at Lookwe—through stony or spherolitic liparites to glassy pitchstones, the percentage of silica varying from 72 down to about 66. A little greenish diopsidic augite is present, and in addition to quartz, orthoclase, or anorthoclase, a fair amount of oligoclase-andesine or even andesine, not uncommonly in porphyritic

* 13, p. 25.


31
32
33
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27
28
Pafuri R.
Nyonda
Letaba R.
Lookwe
Olifants R.
Sabi R.
Komati Poort
Ressano Garcia
Sabie
Moamba
Pessene
LOURENCO MARQUES
Umbelusi R.
Goba
Stegi
Usutu R.
Ingwavuma R.
Pongola R.
Ubombo
Mkuzi R.
Nongoma
Hlabisa
Hluhluwe
Somkele
Umfolozi R.
Umfolozi
Empangeni
TRANSVAAL
SWAZILAND
ZULULAND
PORTUGUESE EAST AFRICA
Karroo Sediments
Lower Basalts
Rhyolites
Upper Basalts
Scale
Kilometres.

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crystals. This shows that some of these lavas are allied to the dacites, and certain of them can more correctly, following Shand, be named "rhyodacite," confirmation of which can be found in some analyses showing excess of soda over potash. All this furnishes strong support for the view, first suggested by Cohen * and subsequently by Prior,† that these acid lavas are differentiation products of the magma from which the basalts were derived.

The intrusive bodies corresponding with the lavas sometimes show the same dacitic affinities, an earlier soda-lime felspar being a characteristic, but no full analysis has been made of any of them.

C. *The Upper Basalts.*

This group is as yet only known from the area between the Lower Komati and Usutu Rivers, where, between Chanculo and a point a little east of Moamba Station, it attains a breadth across the strike of 18 kilometres. In this particular section the country is flattish and exposures not so good as in the more broken region a little to the south and in the Little Lebombo, still now and again the railway cuttings reveal clear contacts between successive flows or else thin beds of sandstone or ash. The dip is consistently eastwards (fig. 3) and, save at one point, flattens out regularly from 20 degrees at Chanculo to 4 or 5 at Moamba, which latter value is attained to the south in the Little Lebombo. Dykes are rare and faulting must therefore be of small account, so that the estimated thickness of 3000 metres cannot be far from the truth.

The rocks are for the most part normal basalts and are like those of the Lower group petrologically, though curiously pipe-amygdaloids were nowhere seen. At kilometre 74 occurred a thin zone of trachytic character, which may perhaps be the extension of the zone of lavas of intermediate composition reported by Young ‡ not far above the base of the group east of Namahacha. At kilometre 61 a cutting has been made through a sheet of banded rhyolite succeeded by pitchstone, pumice, acid breccias, and red sandy tuffs, followed at kilometre 60·5 by basalts of rather basic appearance. This acid intercalation makes cliffs overlooking the river, and may perhaps be the identical zone recorded by Cohen § and by Young ‖ in the Little Lebombo not far to the south. The tuffs recall Young's description of similar thin beds near Goba.

At Bohane a borehole was sunk into the basalts in 1920–21, which attained a depth of at least 362 metres, while near Mugene is another borehole 274 metres deep, from which Young ¶ has described a basalt with

* **2**, p. 261. † **14**, p. 156. ‡ **18**, p. 99.
§ **2**, pp. 264–266. ‖ **18**, p. 101. ¶ **18**, p. 110.

unusually high alumina and also titania (2·57 per cent.); the silica is 46·1 per cent.

The easterly limit of the lavas is marked approximately by a line from Sabié on the Komati River running a little to the east of Moamba, passing between Bohane and Mugene on the Goba railway, and thence south-eastwards to the foot of the rhyolite range. South of the Komati the volcanics pass to the east of this line unconformably beneath nearly flat-lying Cretaceous beds or else beneath a heavy covering of Pleistocene sands; north of that river the country is geologically unknown, though a similar relationship is probably maintained. How far northwards the Upper Basalts extend is problematical.

VI. The Intrusives.

For information concerning the Lebombo volcanicity we must turn to the intrusions, for they shed much light, not only upon the method of effusion, but upon the progress of crustal warping during the cycle of eruption.

Within late years it has become more and more probable that in the Stormberg-Basutoland region the part played by the numerous volcanoes of this area was really a minor one, confined apparently to the earlier stages of eruption. The bulk of the lavas seems to have been emitted from fissures, the consolidated feeders being represented by the Karroo dolerites, that is to say, by the narrow dykes that are so abundantly developed within that region. In the Lebombo area only one possible volcanic neck has yet been detected, whereas dyke-like bodies are legion, forming a dense swarm that trends meridionally and cuts all groups from the basement rocks up to the higher basalts, but becoming progressively fewer in the upper horizons. In contrast, however, to the known areas of Stormberg lavas, the Lebombo belt shows some huge elongated bodies of both basic and acid rock penetrating the lavas, their relationship to the latter being a closely related one unquestionably.

These intrusions can be divided into *three* groups :—

A. (1) The older dolerite dykes, and (2) the basic masses penetrating the basement, the Karroo sediments, and the Lower basalts—the source indeed of the latter;

B. (1) the felsite, and the rhyolite-breccia dykes cutting the Lower basalts and the rhyolites, and (2) the granophyre bodies penetrating the Lower basalts—the source of the acid lavas; and

C. the younger dolerite dykes cutting the entire complex—the source of the Upper basalts.

Five peculiarities attend the narrow intrusions :—first, they show remarkable parallelism ; secondly, though their trend follows closely the strike of the volcanics, they may in places diverge therefrom, as in the south ; thirdly, with relatively few exceptions they deviate from the vertical, heading westwards at angles of between 10 and 20 degrees ; fourthly, they have a platy structure along and parallel to their margins ; and fifthly, in certain demonstrable cases—and probably in many instances—they coincide with planes of slip-faulting.

That they are of widely differing ages is indicated by certain cases of (*a*) intersecting, (*b*) double and (*c*) composite dykes, as well as by other lines of evidence. Detailed petrological work may in the future enable Classes A and C to be distinguished, when cutting the Lower basalts, which is not assured save in a few instances, though that is not considered to be a matter of practical importance.

A. *Older Basic Intrusions.*

1. *Dykes.*—Wherever the writer has had the opportunity of examining the belt between the Letaba River and Hluhluwe, such basic dykes are ubiquitous in the formations below the rhyolites, and it is probably no exaggeration to say that they are set usually from 50 to 100 metres apart, with a width commonly of from 1 up to 8 metres.

Along the Letaba they appear first about 1·5 kilometres west of the Mateolo beacon and are last seen cutting the uppermost of the Lower

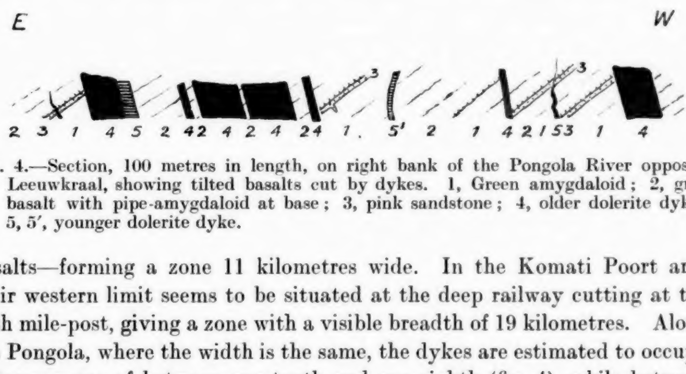

FIG. 4.—Section, 100 metres in length, on right bank of the Pongola River opposite Leeuwkraal, showing tilted basalts cut by dykes. 1, Green amygdaloid ; 2, grey basalt with pipe-amygdaloid at base ; 3, pink sandstone ; 4, older dolerite dyke ; 5, 5′, younger dolerite dyke.

basalts—forming a zone 11 kilometres wide. In the Komati Poort area their western limit seems to be situated at the deep railway cutting at the 70th mile-post, giving a zone with a visible breadth of 19 kilometres. Along the Pongola, where the width is the same, the dykes are estimated to occupy a linear space of between one-tenth and one-eighth (fig. 4), while between Mkuzi and Nongoma this proportion rises to perhaps one-fifth, which is due to their greater individual widths, 15 metres being by no means rare. Halfway between Mkuzi and Hluhluwe the dyke-swarm alters its course from N.–S. to S.S.W. or even S.W., while, on approaching Hluhluwe the

strike of the lavas on the contrary changes from N.–S. to S.S.E., and there is hence a considerable divergence in direction between the effusions and the intrusions. The swarm must dwindle rapidly after this, for in Melmoth, Eshowe, and Empangeni only a few dykes have been noted, though a trend to the S.S.W. can be observed in some of them.

Of these abundant intrusions the majority consist of a fine-grained dolerite with visible porphyritic felspars, but coarser ophitic structures are present in the wider dykes, while other paler types resembling a fine grained diorite can occasionally be found.

2. *Larger Bodies.*—All through Natal and Zululand the Karroo sediments are profusely intersected by dolerite in the form of sills, both concordant and cross-cutting, but between Hluhluwe and the Ingwavuma River the amount of intrusive matter is enormous, forming a veritable framework in which are set mere patches of sediments, the sandstone ledges being rarely unbroken along the hillsides for more than a few hundred metres, the whole still further complicated by the presence of the later, northward-trending dykes. In the south the basal part of the Lower basalts has shared in this extensive invasion, but, on proceeding northwards, concordant sills, if not restricted to the sedimentary division, cannot be common. Along the Stony Spruit near Komati Poort only one crystalline basic sheet was observed among the lavas, which might possibly not be an effusion. None were noted in the Karroo sediments near the Letaba.

On the other hand, linear intrusions are found in the Lebombo region that follow the strike of the Lower basalts, cutting through them and attaining in places a considerable width. The township of Komati Poort stands upon a body, which is 1·5 kilometres in width (fig. 3), a coarse gabbro with long crystals of augite, passing into a diorite on its eastern edge, where it has metamorphosed the adjacent basalts, and is full of xenoliths of the latter, much recrystallised, yet still showing definite amygdales. The exposures of the walls, which are not too good, suggest a steeply inclined body rather than a sheet.

On the left side of the Olifants River, opposite the farm Babat Mond, is a similar intrusion almost 1·5 kilometres wide, cutting steeply through the Lower basalts—situated just over halfway up in that group—doleritic in composition on the margins and gabbroidal in the centre, where it is composed of labradorite, diallage, and abundant platy ilmenite. The date of its introduction can be fixed to within narrow limits by the fact that it is cut by felsites that can be regarded as marking the consolidated feeders for the rhyolites, that is to say, the body was emplaced within the interval represented by the effusion of only some 500 metres of lavas. Not improbably its injection marked the very closing episode of the First or Basic Phase of volcanicity.

Almost midway between this spot and the game ranger's cottage on the Letaba River, and cutting a slightly higher horizon of the basalts, is an intrusion 110 to 130 metres broad, that was traced for fully 3 kilometres along the road, though the exposures of the margins were too poor to show whether it is a dyke or a sill. It is a basic dolerite, becoming in its central part a coarse-grained olivine-norite with much ilmenite and but little felspar, and approaches a picrite in fact; the specific gravity is 3·08. This rock might be regarded as the holocrystalline representative of the limburgites of this neighbourhood, were it not for the fact that it has penetrated volcanics well above the known limburgite zone. Time did not, however, allow of an examination of the higher lying lavas immediately to the east thereof.

B. *Acid Intrusions.*

These bodies display more variety.

1. *Dykes.*—On the Letaba River the upper fourth of the Lower basalts is cut by four parallel dykes each hading to the west, three of them a full 12 metres wide (fig. 2 (8), (8)). The rock is a fine-grained, pink-grey felsite with greenish specks and without visible quartz, but showing in the thin section orthoclase, oligoclase, altered augite, and a finely micropegmatitic base with a few small areas of clear quartz. The third dyke from the west is composite, having selvedges chilled against the basalt walls up to 2·5 metres in width composed of dolerite into which the central felsite is very rapidly transitional. The easternmost one—only 800 metres distant horizontally from the exposed base of the rhyolites to the east—is also 12 metres wide and very similar in habit, but the acid portion is crowded with lumps, streaks, and spots of amygdaloidal basalt, sometimes with sharp, sometimes with indefinite margins, and obviously in varying stages of assimilation, while also containing blocks of a coarse-grained porphyrite with tabular plagioclases up to over 1·5 cm. in length, some biotite, and unusually large ilmenites set in a dark, fine-grained base, the rock being petrologically like some of those intrusions described in A (2).

The westernmost felsite dyke was traced southwards for at least 12 kilometres, and what was taken as its extension was discovered 5 kilometres beyond, close to the Olifants River, cutting through the diorite-gabbro body recorded from this locality, while a second felsite dyke, *en échelon* with the first, on being traced a few kilometres to the south, swells out in this gabbro to a width of 400 metres and forms the ridge supporting the Kudamalabye beacon; it encloses xenoliths of basalt. In the bed of the Olifants near by the basalts are cut, not only by dolerite, but by irregular dykes of felsite, the latter having in places basic margins and showing a

marked banding, always hading westwards in parallelism with the walls of the intrusions.

The evidence suggests most strongly that these acid dykes are the feeders of the rhyolitic lavas of the succeeding division, and that the acid eruptive sometimes took advantage of conduits that were occupied by only partially chilled basic magma. This highly instructive "composite" type of intrusion is well known from among the much older dykes of the Bushveld Igneous Complex, and is finely represented also among the Tertiary injections of the west of Scotland.

At a spot 400 metres below the Komati Poort railway bridge the river falls over a ledge of felsite having xenoliths of altered basalt. It strikes northwards, and gives off on the right band an offshoot (having basic margins and numerous basic xenoliths), that trends eastwards and cuts transversely through both the basalts and the north-south dolerite dykes that intersect the latter. Here we have further evidence that certain of the basic dykes preceded the acid ones.

The above-mentioned acid dykes all penetrate the Lower basalts, but within the rhyolite group just east of Ressano Garcia several dyke-like bands of brecciated and banded rhyolitic material of peculiar character cut the acid lavas, having a north-south strike and a hade to the west, or else a nearly vertical attitude; the last is a feature of some importance. They are apt to be overlooked amid the similar rhyolitic rocks, and are probably more numerous than one would suspect. They seemingly represent the consolidated feeders to higher acid flows, the eruptions through them having been of an explosive character.

In the ravine of the Mkuzi River, on the right-hand side, 2 kilometres from the (western) entrance, a gap in the dipping, compact red rhyolite about 24 metres across is filled with nearly horizontally-bedded greenish-brown, rough-weathering rhyolitic lava, coarse-grained and crumbly. This may perhaps mark a volcanic pipe or else a wide fissure of eruption. It might be interpolated that recorded cases of extensive emission of rhyolitic lavas from fissures are relatively few, but a good example is known from Corsica,* where the flows were fed from a dyke-swarm 17 kilometres wide.

2. *Granophyre Bodies.*—South of Komati Poort and extending into Swaziland is the huge intrusion composing the ridge of the Mananga Mountain, described by Kynaston † as cutting through the upper portion of the Lower basalts, a body over 30 kilometres in length with a maximum width of 1·5 kilometres, that follows the slightly curving strike of the volcanics. It is composed of fine-grained, pale augite-granite or granophyre, and was correctly regarded by him as marking not improbably a great channel from which were derived the acid lavas of the chain situated only a

* 15, p. 120. † 8, p. 28; 10, pp. 45–48.

trifling distance to the east. It is cut by narrow dolerite dykes, one of which is recorded as trending north-south.

More to the south within Swaziland, Garrard * has mapped a similar large, but forked, granophyre body piercing the basalts near Stegi, the eastern boundary of which is shown in contact with the base of the rhyolites. He is in agreement with Kynaston's interpretation of these masses.

C. *Younger Basic Dykes.*

Such are patent in the Upper basalts and in the rhyolites, but cannot be discriminated with any assurance when in the Lower basalts. In fig. 4 a dyke (5) shows a chilled contact against a pre-existing intrusion, and probably belongs to this younger suite, while the nearly vertical attitude of (5′) hints at a similar relationship. Double basic dykes were observed in the rhyolites east of Ressano Garcia at kilometres 79·2 and 82·8. East of the Letaba River, and again in the Mkuzi Poort, no basic dykes were seen intersecting the rhyolites, though not improbably they would be represented still farther to the east. Anderson † has, however, recorded one of "augite-basalt" to the south of the Umsinduzi River that cuts through the basal part of the rhyolite group and has a strike a little north of east. Such a direction is unusual and was only noticed at one point, on the eastern side of the Letaba River in the bed of the Makadye stream, where such an oriented basic intrusion was cut through by two parallel north-south dolerite dykes.

Along the Komati River dykes are frequent in the rhyolites (fig. 3), fully thirty-five having been picked up in that belt, ranging in width from a decimetre to bodies 6 metres or more, striking north-south and dipping westwards at angles of from 70 to 80 degrees, and hence not normal to the stratification of the lavas. Some are vertical, while a few hade very slightly to the east, and are of significance in suggesting a very late stage for their intrusion, when crustal tilting had practically ceased. They are usually fine grained with platy jointing parallel to the walls and a marked cross-jointing, while some contain tiny vesicles in the central parts. A dyke over 12 metres wide at kilometre 83·3 is of a coarser grey diorite-gabbro.

In the Upper basalts dykes are decidedly scarce (even making allowance for the poorer exposures along the railway), and are usually narrow; the easternmost of these, 6 metres broad, was noticed at kilometre 63·7, but doubtless such intrusions would occur beyond that point, but off the line of section.

No work has been done on the petrology of these dykes, but the account

* 16, p. 81. † 6, pp. 60, 62.

given by Henderson * of an example piercing the very top of the Lower basalts, and presumably belonging to this younger suite, may be taken as typical; the analysis shows a dolerite with 50·42 per cent. of SiO_2.

Alkaline Intrusions.—From between Lourenço Marques and the Little Lebombo Young † has recorded several dyke-like or elongated outcrops of alkaline rocks—nepheline-syenite-porphyry and vogesite—near Pessene and Bohane, which appear to be of intrusive character, but the surrounding formation is concealed, though the Upper basalts cannot lie at any great depth. It may well be that they pierce the Cretaceous Beds and are therefore of post-Lower Cretaceous age, but no direct evidence has yet been obtained upon this point. Similar alkaline rocks of late Mesozoic or early Tertiary age have been described by Holmes from Northern Moçambique, but comparisons can also be made with the alkaline lavas within the Lupata Gorge between Tete and Sena on the Lower Zambesi. These last have been considered by Mennell ‡ as of post-Karroo age, but Anthoine and Dubois,§ on the contrary, regard them as forming an integral portion of the Karroo system, the succession being (1) Guengue Sandstone, (2) Sungo phonolites, (3) Lupata lavas, (4) Bandar basalts.‖ There is just a possibility, therefore, that the alkaline rocks of the Little Lebombo area mark the closing phase of Karroo volcanicity.

VII. The Eruptive Cycle in the Lebombo.

The data set forth enable the volcanic history of the belt to be deduced in more than mere outline.

As pointing to the intrusions being the consolidated feeders for the various flows are the following:—

(1) The absence of central vents; (2) the crowding of the basic dykes in the visible area of the Lower basalts; (3) the linear nature of the basic holocrystalline bodies in the latter, some of them being of pre-rhyolite age; (4) the felsite dykes and granophyre bodies in the upper portion of the Lower basalts close up to the base of the rhyolites; (5) the less numerous basic dykes in the latter; (6) the relatively few dolerite dykes in the Upper basalts; and (7) the petrological resemblance between each suite of lavas and the corresponding intrusions.

That the belt coincides with a zone of *crustal tension* is obvious: even the large basic and acid intrusions have a marked linear arrangement parallel thereto.

Considering for the moment only the actual *visible* portion of the lower volcanic group—a strip a score of kilometres wide—it can be computed that

* 13, pp. 29, 30. † 18, p. 103. ‡ 19, p. 166.
§ 21, p. 751. ‖ See Postscript.

in its midsection the basic dykes must occupy a total linear distance of between 2 and 4 kilometres—that is to say, exclusive of the large bodies. The westerly edge of the dyke-swarm is very sharply defined, crossing at a very slight angle the line of outcrop made by the base of the Karroo system. Between the Letaba and the Komati this line runs just within the crystalline rocks ; thereafter it gradually passes into the area of Karroo sediments, but remains within the latter down to the Mkuzi River at least. The eastern limit is of course masked by the uppermost lavas and by Cretaceo-Tertiaries, but, assuming the easternmost basic dyke between Movene and Moamba to represent its seaward limit, the maximum width of the swarm would not be less than 45 kilometres and doubtless well exceeds that figure. The stretching of the crust within this belt must therefore have been quite considerable.

Furthermore, the slip-faulting accompanying some of the dyking (fig. 4) would imply an additional extension of the crust, for the various crustal slices have in dropping caused the strata to cover a greater space than otherwise. No faults were observed without igneous rock parting the faces, except in certain cases similar to those shown towards the opposite ends of fig. 4, where the upward prolongation of a narrowing dyke is marked by a fracture with slight dislocation, a feature suggesting that displacement and injection were synchronous and connected. Dyking and faulting must together have been responsible for a good deal of crustal extension, which in the central part of the belt may possibly have amounted to not less than 15 per cent.

For investigating the progress and the amount of the *crustal warping* we are able to utilise the valuable property shown by dykes of deviating but little from the vertical upon injection, as is so finely displayed in the Cape-Natal Drakensbergen.

The fact that throughout the Lebombo region the dykes are but rarely vertical, and dip westwards at angles of from 80 to 70 degrees, proves of the utmost moment in signifying that the *Lebombo Monocline came into being during the eruption of the lavas.* Wherever the dip of the sediments or volcanics is low, *e.g.* in the extreme east and west, there is a tendency for the dykes to cut the latter almost at right angles, but where the tilting of the strata is considerable, that is to say towards the axis of the monocline, the intrusions are no longer roughly perpendicular to the flows, but intersect the latter at angles so small at times as only 60 degrees, *e.g.* to the east of Ressano Garcia. It might be noted further that this axis is slightly oblique to the trend of the Range. From a position within the rhyolites a kilometre east of Ressano Garcia it passes by degrees, when traced southwards, into the Lower basalts, and crosses the Pongola River at about the spot where fig. 4 was taken—about two-thirds up in that group. Outwards, both to east and west, from this axis the dip decreases, while, where the Karroo

beds reappear far to the west on the highveld of Nongoma, Ngotshe, and Piet Retief, they are horizontal.

In interpreting these phenomena it is clear that—

(*a*) *all* the warping could not have *preceded* the dyking, seeing that the effusions themselves must have ascended by means of the dyke-planes ;

(*b*) *all* the warping could not have *followed* the dyking, otherwise in the axial part of the monocline the intrusions would have shared equally in that tilting, which is not the case ;

(*c*) the warping could hence have occurred only *during the eruptive period*.

This latter must have been a lengthy one, and some narrower limits to this orogenic movement are desirable. Now the base of the Stormberg volcanics in the eastern part of the Union is found to consist invariably of the Bushveld (Cave) Sandstone without appreciable discordance. The earliest lavas, welling out of fissures or pouring out of vents, must have spread out over an immense plain formed by that sandstone. Any hade displayed to-day by the responsible dykes must be due to subsequent tilting of the whole, wherefore it follows that the monocline had not yet been initiated at the very commencement of the first eruptive phase.

In the illuminating section on the Pongola River (fig. 4), right on the axis of the flexure, the lavas concerned are fully two-thirds up in this basalt succession. Presumably the remaining third of this group issued from fissures that are represented by certain of the very dykes exposed at this spot. The intrusions, nevertheless, cut the basalts obliquely to their stratification, showing that some tilting had already occurred, though not the full amount, as indicated by their westerly hade. This feature is even more conspicuous farther to the north at Ressano Garcia (fig. 3). While many of the dykes in the lower part of the Upper basalts possess a westerly hade, those in the still later effusions exposed to the east are not far removed from verticality, while certain basic dykes—manifestly feeders for those basalts—in the highly tilted rhyolites between kilometres 84 and 85·5 are either vertical or even hade slightly eastwards, all of which goes to show that the warping had largely been accomplished by the middle at least of the third eruptive phase.

The few vertical rhyolitic " fissures " near Ressano Garcia possibly acted as feeders to the sporadic acid flows recorded to the east, high up in the third group.

On this reasoning, which is admittedly not unimpeachable, the *crustal bending began during about the middle of the Lower and ended before the middle of the Upper basaltic phase ; its optimum would therefore have fallen within the Middle or Rhyolitic period of volcanicity.*

It has long been recognised that the " plateau basalts " characterise

regions in which there has been little differential movement of the crust. According to one geological school they represent the welling out of the universal primitive and undifferentiated basic substratum (the *sima*). The rhyolites, on the other hand, demand a high degree of differentiation within this primitive magma, and by many have been regarded as originating from the reaction of the latter upon the outer siliceous portion of the crust (the *sial*); that is to say, they are syntectic and secondary. Under this view crustal warping could well have aided the concentration of such an acid differentiate and its rise to the surface, wherefore the sequence basalt-rhyolite-basalt would appear to point rather definitely to some such inter-crustal movement during the relative quiescence of plateau eruption.

In a stimulating address Evans * has pointed out how such a progression from ultrabasic to acid could have been effected, and his views can be applied to the Lebombo with but slight modification. The acid magma is regarded by him as a salic, more viscid differentiate, accumulating at the apex of a "magmatic wedge." After the escape of a fraction of the more fluid ultrabasic and basic portion, this acid reservoir might, as the result of tectonic causes, be tapped until exhausted or until warping ceased. Flexing, by placing the outer part of the crust in tension and the inner in compression, would tend to squeeze out magma occupying channels in the latter. The Olifants River and Komati Poort gabbros and the Mananga and the Stegi granophyres inferentially represent such wedges, though on a very much smaller scale presumably. It is not intended to discuss the Lebombo region as a "petrographical province," but it should be pointed out that, while the acid rocks seem to be normal, certain of the basic ones are high in titanium oxide, evinced in hand specimens by the amount of ilmenite.

A curious point in our problem arises out of the fact that in the west the narrow slices between the dykes have their downthrows, not towards the east, as might be expected in view of the downwarping on that side of the belt, but in precisely the opposite direction. Such slip-faulting seems, however, to have operated mainly, if not exclusively, during the first eruptive phase. In visualising the circumstances, we must realise that the Lebombo volcanic belt did not stand alone, but formed either an integral part of the main area of Stormberg volcanicity of Basutoland, Natal, and the Central Transvaal, or a neighbouring outlier thereof, and that the Lower basalts, if they were not united in the past with their equivalents of the Springbok Flats 225 kilometres distant, at least extended far to the west of their present highly eroded outcrop. The writer † has pointed out that towards the close of the Rhaetic a great volume of basic magma underlay South Africa, forced into that position seemingly by the lateral pressures

* 20, p. cvii. † 17, p. 36.

that had been crumpling up the southern part of the Cape. With the cessation of such diastrophism and the consequent relief of pressure within the northerly "foreland" region, this molten material became able to penetrate into the overlying strata and did so through a network of cracks, pouring out at the surface both from volcanic pipes and fissures and consolidating below ground in the form of a plexus of dolerite sheets and dykes.

The sequence of events on the eastern side of the sub-continent may hence be pictured somewhat as follows :—

1. The basic magma was driven to higher levels within the sial under pressure exerted from the south-south-west.

2. An east-west tension developed in the Lebombo region and took control of magmatic injection.

3. A line of weakness was produced running north-south, and into it was driven a great magmatic wedge, within the upper portion of which there came about a gradual accumulation of acid differentiate, partly through assimilation, partly through gravitative influences.

4. On the western side of this wedge fracturing in a meridional direction took place repeatedly and basalts (and limburgites) were erupted that spread out to east and west from each fissure.

5. With each rifting of the crust there was a small subsidence of the territory to the west, indicating that the material emitted from the fault-plane was in the main drawn from this *interiorly situated reservoir.* It can indeed be surmised that the acid wedge immediately to the east, being at a lower temperature because of its mode of origin, superior position, and viscous condition, gave support to the section of the crust directly overlying it, wherefore the basaltic injection and slip-faulting operated mainly on the western side of the belt.

6. The hinge-line was initiated, basic wedges were driven into the upper portion of the Lower basalts, to consolidate as gabbro, and the *locus* of fracturing was shifted eastwards.

7. The acid reservoir was ultimately tapped and rhyolites were discharged from meridional fissures, the explosive character of the eruptions being indicated by breccias and tuffs. Crustal warping progressed, due perhaps to the transfer of acid magma from beneath the eastern half of the belt, and slip-faulting would accordingly have come to an end on the west. Through warping, the surface of the lava field would have been kept sloping eastwards, and the erupted matter would have been discharged mainly in that direction and so have accelerated the subsidence on that side and stimulated the sub-crustal transfer of magma from east to west.

8. A renewal of tension is indicated by immense acid wedges in the shape of the granophyre bodies, but the width of this zone of irruption seems to

have been narrow—apparently not much more than a dozen kilometres in the central section.

9. The reservoir of acid magma became exhausted and basalts were once more emitted from tension rifts. The monocline had not ceased growing, which suggests that the basic matter was now being drawn from beneath the *eastern* area. Perhaps for that reason sporadic eruptions of rhyolite occurred.

10. Tension became less and less and volcanic action waned, due either to exhaustion or to the rising of the interior of South Africa with the Lebombo as the hinge-line, as suggested by other lines of evidence.

11. The alkaline rocks of the Little Lebombo area may perhaps have been intruded as an expiring effort, though of this there is as yet no direct proof.

The above outline, while in some ways admittedly speculative, appears to be in essential accord with the facts, though future work will doubtless require modifications to be made in this story, but the cycle corresponds more or less closely with some that have been worked out in other parts of the world, for example in the case of the Tertiary volcanicity of Queensland. The slight evidence available favours an easterly migration of the *locus* of rifting and hence implies a broad, but relatively low, pile of well-stratified lavas rather than a narrow chain with enormous height.

There is but little to show under what climatic conditions these eruptions took place. The Bushveld Sandstone was undoubtedly accumulated in a period of semi-aridity at the close of the Rhaetic. The absence of weathering of the upper crusts of the lava flows, save in the two instances referred to in Section V, suggest, first, that the eruptions followed one another without any lengthy interval; and, secondly, that the climate was not a humid one, while the thin intercalations of red, ashy sandstone and tuff in the Upper basalts do not materially differ from those found in the Lower group and in their equivalents in the Stormberg-Basutoland region. Presumably, therefore, the climate continued dry throughout the eruptive period.

The three phases of eruption must have embraced a considerable time-interval, but, until determinable fossils have been obtained from some of the upper tuffs, no superior age-limit can be set, though evidence from Pondoland shows that erosion of the Lower volcanics was active by the very commencement of the Cretaceous Epoch. In Southern Argentina, which was linked to South Africa at that time and displays a remarkable geological parallelism therewith, the vast outpourings of quartz-porphyries (rhyolites) at the close of the Trias-Rhaetic are overlain by marine Jurassics (Dogger =Lower Oolite), and, if their equivalence with the Lebombo volcanics be conceded, the latter would be of Liassic age. The Lower Zambesi succession should be of high importance in this connection, if palaeontological evidence could only be obtained therefrom.

It is not impossible that during the Middle or Upper Jurassic some part of the eastern side of the belt was lapped by the ocean that inundated sections of East Africa and Madagascar, but, within the known portion, no strata have so far been discovered older than the Lower Cretaceous (Aptian). The latter nevertheless demonstrate a considerable subsidence of the Lebombo region by the beginning of the Cretaceous Epoch.

VIII. Post-Volcanic History.

In the twenty years that have elapsed since the " Lebombo Richtung " became the subject of discussion between Passarge * and Penck,† our knowledge, perhaps not so much of the belt itself, but of the areas to the south and west thereof, has advanced materially, and many doubtful points have been decided as well as fresh ideas developed. We are in a better position, furthermore, to evaluate the intra-Cretaceous movements that have played so important a part in the tectonics of South Africa, while the present study extends our knowledge backwards by assigning the growth of the Lebombo Monocline to the Liassic with much probability. This great structure is known to continue through Natal and Pondoland in a direction a little west of south, though here and there displaced by intense oblique or transverse faulting of mid-Cretaceous date, coupled with considerable further bending within certain sections.

The fact that the eastern side of the monocline is overlapped by marine Cretaceous—from Pondoland to Sabié on the Komati River at least—renders it probable that that relationship will continue along the northern half of the Lebombo. While the strata at the foot of the Range belong to various divisions of the Cretaceous—from the Aptian to the Senonian—they display a lithological sameness, the presence of calcareous sandstones and conglomerates with pebbles of rhyolite, agate, quartz, etc., implying fairly shallow-water conditions. The inclusions of quartzites and other pre-Karroo rocks in such coarser strata are highly significant, since they could only have been derived from the *western side* of the Range. It is not improbable, too, that there has been much stripping of the Cretaceous (or Tertiary) Beds, and that the latter extended originally for some distance westwards up the eastern slopes of the Lebombo. Direct evidence therefor is wanting, it is true, but from latitude 25 degrees northwards the geology remains almost unknown.

Astonishing is the presence around the Lookwe beacon on the crest of the Range near the Letaba River of isolated water-worn pebbles of quartz, quartzites of various kinds, chert, agate, and rhyolite scattered over the rhyolite surface, which fact points to the top of the Lebombo as being the

* 11. † 12, p. 247.

remnant of a peneplain that supported gravels in the past. To-day a deep erosion-trough 100 kilometres wide separates this ridge from the higher Drakensberg Escarpment to the west, from which alone could those sedimentary and metamorphic pebbles have been derived. The writer was furthermore informed by Mr. Ledeboer, game ranger on the Letaba River, that the portion of the belt situated within Portuguese territory between the Shingwedzi and the Limpopo River consists of a plateau covered by a sheet of boulders and pebbles and having a strongly dissected eastern scarp. Specimens brought back by Mr. Murray from the Boundary line in that section show the presence of a sheet of hard surface limestone and pebbles of quartz, quartzite, and metamorphic rocks. On the Limpopo, between latitude 22½ and 24 degrees, Elton * and Erskine † recorded red sandstones and conglomerates of unknown age, giving rise to cliffs.

The wonderfully even crest-line of the Range, and the way in which the tilted rhyolites are transected, indicate a lengthy period of active planation following the development of the monocline. The trough of the Lowveld could not then have been in existence, and the Lebombo peneplain must have extended westwards to meet the higher ground in that direction. As we know, there was in the south of the Union in the early Tertiary a very widespread planation followed by upheaval over the interior of the continent, as the result of which the drainage system running over this peneplain became deeply incised. The very similar sequence of events in the Lebombo region strongly suggests synchronism in the two areas. Stages in the dissection of the peneplain and in the evolution of the Lowveld are indeed indicated by thick gravels capping the elevations on which stand the Sakashaiengwe and Shamariri beacons between the Letaba and Olifants, the second of which rises to almost 100 metres above the latter river. Quite possibly the main drainage lines were " antecedent " to the Range.

IX. Summary.

1. The belt of the Lebombo follows the thirty-second meridian through an arc of nearly six degrees.

2. It is composed of volcanic outpourings of Upper Stormberg (probably Liassic) age succeeding conformably Permo-Triassic Karroo sediments, the whole bent into a monocline with drop on the eastern side.

3. The volcanics can be triply divided into a Lower basaltic, a Middle rhyolitic, and an Upper basaltic group, but in the northern half of the belt limburgites are present at the base, and in the extreme north and north-west alkaline basalts as well.

4. Corresponding with this triple division are the three main topo-

* 1, p. 1. † 3, p. 45.

graphical features—the western Lowveld, the Range proper, and the eastern Foothills, together with the Little Lebombo.

5. The dip of the formations involved is eastwards, usually at angles of between 5 and 20 degrees, but on approaching the axis of the flexure their inclinations rise to 30, 40, or occasionally to 60 degrees, flattening out towards the east, in which direction the volcanics pass unconformably beneath Cretaceous or younger beds.

6. The maximum thickness of the volcanics is probably at least 9000 metres and may even have exceeded 10,000 metres.

7. Intrusive into the sediments and lavas is a swarm of doleritic dykes with a north-south trend, parallel to the Range, and with small westerly hade, while within the Lower basalts are felsite dykes and larger linear bodies of dolerite, gabbro, and granophyre.

8. The distribution, behaviour, sequence, and composition of these basic and acid intrusions cause them to be regarded as the consolidated feeders of the material erupted, the volcanism being of the fissure type. The larger intrusions may have functioned in a similar manner. Some of the dykes have been introduced along slip-faults with downthrow to the west.

9. Crustal tension in an east-west direction is specifically indicated throughout the eruptive period.

10. The growth of the Monocline can with good reason be dated to the middle portion of that period, and its development is considered as indirectly responsible for the explosive and acidic character of the material emitted during the second volcanic phase, which occurred between the effusion of two " quiet " suites of plateau basalts.

11. Both the extrusive and intrusive suites can be regarded as products from a single basic intercrustal reservoir within which differentiation had been brought about.

12. Erosion operated probably from the mid-Jurassic onwards, while the eastern side of the structure was lapped by the ocean during various stages of the Cretaceous.

13. The drainage of this region is of the superimposed kind, initiated upon a peneplain that formerly stretched from the interior Highveld eastwards across the Range, and which became intensely eroded during the Tertiary as the result of upheaval of the continent.

Postscript.—Just after the text went to press Dixey (**24**) published the important record of the discovery of a basalt-rhyolite-basalt succession in the Karroo volcanic sequence in Portuguese Territory situated in the area between the Shiré and the Zambezi Rivers.

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THE LITERATURE OF CAYLEYAN MATRICES.

By Sir THOMAS MUIR, F.R.S.

1. More than thirty years ago "A List of Writings on the Theory of Matrices (1857–1893)" was published by me in vol. xx of the *American Journal of Mathematics*. It appeared not as an independent communication, but as a kind of appendix to a paper in which the theory was put to practical use. In thus associating practice and theory I was humbly following a good example: for it will be remembered that Cayley's foundational memoir of 1857 had been accompanied from the first by another on "The Automorphic Transformation of a Bipartite Quadric Function," and that the two memoirs appear in contact both in the *Philosophical Transactions* and in the *Collected Mathematical Papers*. It was my intention, as stated at the time, to follow up the List with another supplying any missing items for the period 1857–1893 and bringing the whole up to a later date. Nothing came of this, however, such work being found to be incompatible with the absorbing duties of my new post and with my altered distance from the requisite books of reference.

2. When in 1900 circumstances in a manner necessitated me returning to my bibliographical work on Determinants, the title-slips dealing with Matrices were not thrown away but, after being roughly examined and arranged, were given a pigeon-hole to themselves, so as to be ready for consultation when wanted. The same course has since then been followed during the preparation of all the similar Lists, from the third published in 1903 to the ninth and latest published in 1927. In this way seven published lists devoted to determinants have had laid away as counterparts seven miniature manuscript lists devoted to matrices; and it is these last that form the greater portion of the contents of the list that herewith follows. All that was additionally necessary was to rearrange the whole in a single chronological order, and then to do one's best to check the relevancy of each title-slip separately.

3. In so acting as critic and arbiter of my own collection the aims have been (α) to retain in the list every item that concerns itself directly with 'Cayleyan matrices'; (β) to retain a sufficiency of items that in strictness are only *applicational* as regards the theory; (γ) and to be somewhat less liberal to those that deal with generalisations of the theory or with cognate algebras that only throw a side-light on it.

4. The first of these aims is the least easy of fulfilment, because unfortunately, especially in later times, the term matrix as used in a title is rarely unambiguous. From being a coinage at first fought shy of—used indeed for a quarter of a century by its introducer only—it has come now to be handled with a certain careless freedom. The first noteworthy impulse to its use in Cayley's sense was due to Sylvester; but Sylvester's followers were not always as understanding and as careful as himself, the consequence being that we now speak not only of the determinant of a matrix but also of the matrix of a determinant, the rank of a matrix, the invariant factors of a matrix, and so forth. One of the first of such extensions of usage was entirely uncalled for, especially in England, namely, to make it take the place already satisfactorily occupied by the word 'array.' How satisfactorily this was will be readily seen on looking through textbooks of determinants like Scott's, in use from 1880 onwards. In Italy matters were similar; for, although no needless supersession was there made, yet from 1897 the same secondary usage became, as it were, the primary and authorised usage, the textbooks referring to no other. And so, as a consequence, writings on 'matrici' came to be referred to outside Italy as dealing with that very different subject, the algebra of matrices: for example, Nicoletti's paper of 1902, which in reality treats merely of compound determinants.

5. A capable historian, who would now make skilful and appropriate use of the 172 writings here chronicled, would confer a lasting benefit on the mathematical world. And he would certainly add further to his credit if in the course of his work he made manifest by precept and example an irreproachable mode of using in each other's company the terms *array*, *determinant*, *matrix*.

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Rondebosch, South Africa,
5th December 1928.

SOME DERIVATIVES OF THIAZOLE.

By James Leonard Brierley Smith and Reuben Hillel Sapiro.

In an earlier communication (Smith and Flack, Journ. S.A.A.A.S., 1924, p. 227) certain new derivatives of thiazole were described.

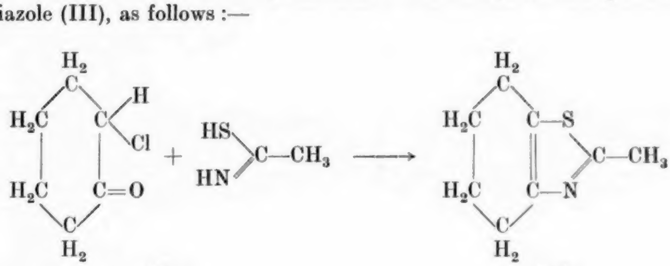
In certain cases general condensation processes employed in the synthesis of thiazole derivatives appeared to fail, and the possible reasons for this were discussed.

The present communication is largely an extension of the work previously described.

It was shown (*loc. cit.*) that certain α-halogenated cyclic ketones appeared unable to condense with thio-amides to produce *bz*-hydrobenzothiazole derivatives, and this was attributed to the tendency of these halogenated ketones to assume the form (I), since there would appear to be little doubt that this form would be non-reactive.

I.

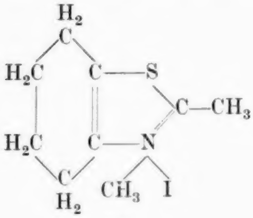
We have, however, succeeded in condensing α-chloro cyclohexanone (II) with thio-acetamide, with production of 2-methyl-*bz*-tetrahydrobenzothiazole (III), as follows :—



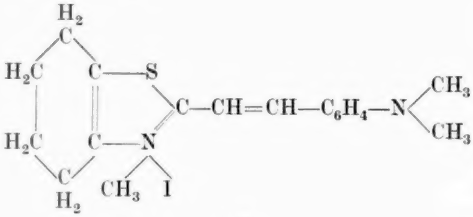
II. III.

This is remarkable in view of the evidence previously obtained, but may be attributed to the close resemblance of cyclohexanone to the aliphatic ketones, *e.g.* acetone.

As would be expected, this condensed thiazole system shows more resemblance to the simple mononuclear thiazoles than to the benzothiazole series. The methiodide of this derivative (IV) was condensed with dimethylamino-benzaldehyde, with production of 2-*p*-dimethylamino-styryl-*bz*-tetrahydrobenzothiazole methiodide (V).



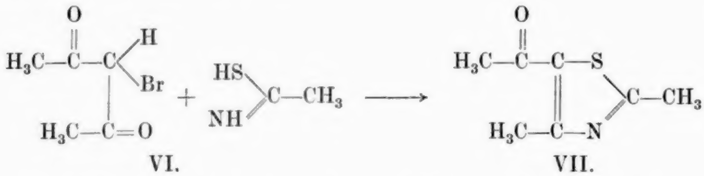
IV.



V.

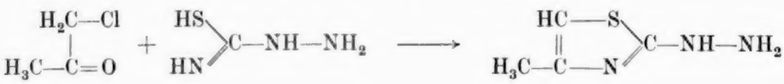
This dyestuff resembles closely, in colour, etc., the corresponding dyestuffs obtained from the mononuclear thiazoles rather than that obtained from benzothiazole itself.

Other derivatives of thiazole have been prepared. Bromo-acetylacetone (VI) was condensed with thio-acetamide with production of 2-4-dimethyl-thiazolyl-5-methyl ketone (VII).



VI. VII.

Attempts have also been made to obtain a thiazole derivative of hydrazine (X). It was anticipated that this might result from the interaction of monochloro acetone and thiosemicarbazide (IX), as follows :—

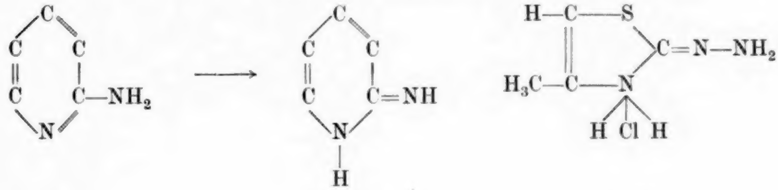


IX. X.

We have failed to isolate the base (X), which is not surprising, since it may be expected to be extremely unstable, by analogy with the behaviour of α-amino pyridine derivatives, although 2-amino thiazole can be

diazotised, and the diazo compound so produced does not appear to be excessively unstable.

We have, however, isolated what appears to be its mono-hydrochloride (XIII). That X should function as a mono-acidic base would be expected from the behaviour of α-amino pyridine (XI), which is itself a mono-acidic base, owing, it has been suggested, to its existence in the form (XII).



XI. XII. XIII.

This would indicate that if this hydrochloride exists we should expect it to have the structure (XIII).

All attempts to isolate the free base (X) failed ; on treating the hydrochloride with alkali, evident decomposition with production of tarry matter took place, and no definite product could be isolated from the mixture.

The hydrochloride itself does not keep, but darkens rapidly in colour, and is transferred to tarry matter.

In the literature at our disposal no evidence of the existence of even β-pyridyl hydrazine can be found.

Experimental.

2-*Methyl-bz-tetrahydrobenzothiazole*, $C_8H_{11}NS$.

Monochloro cyclohexanone.—We have been unable to find any account of this substance, or of attempts at its preparation. Bromination of cyclohexanone in carbon-disulphide solution yielded a dark, tarry mass, which is not surprising in view of the ease with which this cyclic ketone undergoes self-condensation in the presence of acid. In order to prevent undesirable side reactions, cyclohexanone was chlorinated in the presence of calcium carbonate.

Chlorine gas was led into a mixture of cyclohexanone (50 grm.), calcium carbonate (25 grm.), and water (30 grm.) until the calcium carbonate had all dissolved in the aqueous layer. The acid remaining was neutralised by the addition of excess of calcium carbonate, and the oily layer separated and dried over sodium sulphate.

On fractional distillation *in vacuo*, the oil yielded a mixture of mono- and of di-chloro cyclohexanone (10 grm.). This boiled at 120–130° at

25 mm. pressure, and it was not found practicable to separate the monochloro derivative in a pure state owing to its obvious instability.

The distilled oil evidently contained about 70 per cent. of the monochloro cyclohexanone.

Analysis.—0·2006 grm. gave 0·2471 grm. AgCl, whence Cl=30·5 per cent.

C_6H_9OCl requires Cl=26·8 per cent., $C_6H_8OCl_2$ requires Cl=42·5 per cent.

The above oil (10 grm.), thio-acetamide (6 grm.), and alcohol (5 c.c.) were heated to 100° for thirty minutes, when it became evident that condensation had taken place, a crystalline salt separating. The mixture was boiled with dilute hydrochloric acid, and the solution freed from oily impurities by extraction with ether and filtration of the aqueous layer.

Addition of excess of caustic soda to this solution produced an oil, which was extracted with ether. The ethereal layer was dried over caustic potash and, after evaporation of the ether, a brown oil remained which was distilled.

2-*Methyl-bz-tetrahydrobenzothiazole* (4 grm.) passed over at 230°/715 mm. as a colourless highly refractive oil, with a penetrating odour resembling that of 2-4-dimethyl thiazole.

Analysis.—0·1706 grm. gave 0·2588 grm. $BaSO_4$, whence S=20·8 per cent.

$C_8H_{11}NS$ requires S=20·9 per cent.

The thiazole is insoluble in water, but is readily soluble in organic solvents.

Picrate of 2-*methyl-bz-tetrahydrobenzothiazole.*—Orange-yellow tufts of needles from alcohol, which melted at 120°. (Mixed melt with picric acid 70–80°.)

Platinochloride of 2-*methyl-bz-tetrahydrobenzothiazole* $(C_8H_{11}NS)_2.H_2PtCl_6$.—Copper-coloured plates from water, in which it is extremely soluble.

0·3181 grm. gave 0·0865 grm. Pt, whence Pt=27·2 per cent.,
$C_{16}H_{24}N_2S_2Cl_6Pt$ requires Pt=27·2 per cent.

2-*Methyl-bz-tetrahydrobenzothiazole methiodide*, $C_8H_{11}NS.CH_3I$.—This was prepared by heating the base with one equivalent of methyl iodide in a sealed tube for forty-eight hours at 60°. The oily contents of the tube crystallised on cooling, and were separated from some tarry matter by solution in water and filtration. The aqueous solution was evaporated to dryness on the water-bath, and extracted with hot absolute alcohol. On slow evaporation of the alcohol in a desiccator, colourless crystals of the methiodide were obtained.

Analysis.—0·0666 grm. gave 0·0515 grm. AgI, whence I=41·8 per cent.

$C_9H_{14}NSI$ requires I=43·0 per cent.

This salt is extremely deliquescent, and exceptionally soluble in both water and alcohol. This high solubility in water or alcohol appears to be characteristic of all thiazole methiodides containing a substituent in the 5-position.

2 - *p* - *Dimethylamino* - *styryl* - *bz* - *tetrahydrobenzothiazole methiodide*, $C_{18}H_{23}N_2S.CH_3I$.—On heating a solution of the methiodide described above (4·5 grm.), *p*-dimethylamino benzaldehyde (2 grm.) in alcohol (40 c.c.), with piperidine (0·4 c.c.), a red colour developed immediately. After boiling for four hours, the solution was cooled, when a crystalline dyestuff (4 grm.) separated. This was collected and recrystallised from methyl alcohol, when the dyestuff was obtained in the form of red needles with a brilliant peacock-green reflex, which melted and decomposed at 248°.

Analysis.—0·2397 grm. gave 0·1310 grm. AgI; 0·2337 grm. gave 0·1302 grm. $BaSO_4$, whence I=29·5, S=7·63 per cent.

$C_{18}H_{23}N_2SI$ requires I=29·8, S=7·51 per cent.

The colour in solution, which is a deep orange, resembles that of the dyestuff obtained from 2-4-dimethyl thiazole methiodide, and is much less intense than that of the dyestuff obtained from 2-methyl benzothiazole methiodide.

Details of its sensitisation spectrum have not yet been obtained.

2-4-*Dimethyl-thiazolyl*-5-*methyl ketone*, C_7H_9ONS.—Acetylacetone was prepared according to the directions of Claisen (Ann., *277*, 1893, p. 168). This was brominated in the presence of calcium carbonate in alcoholic solution, when a dark brown, partially decomposed product was obtained. This crude bromo-acetylacetone (15 grm.) was treated with thio-acetamide (10 grm.) and alcohol (10 c.c.), when a violent reaction took place, with evolution of heat. The reaction was moderated by cooling, and finally completed by heating on the water-bath for half an hour.

The dark-coloured reaction mixture was freed from tarry matter by solution in dilute hydrochloric acid and filtration. Addition of excess of caustic soda to this solution produced an oil, which was extracted with ether. The ethereal solution was separated and dried over sodium sulphate.

Evaporation of the ether left a red oil and, when this was distilled, 2-4-*dimethyl-thiazolyl*-5-*methyl ketone* passed over at 227°/715 mm. as a colourless oil, with a not unpleasant odour.

Analysis.—0·1504 grm. gave 0·2215 grm. $BaSO_4$, whence S=20·2 per cent.

C_7H_9ONS requires S=20·6 per cent.

Semicarbazone of 2-4-*dimethyl-thiazolyl*-5-*methyl ketone*, $C_7H_9NS=N.NH.CONH_2$.—Colourless needles from alcohol, which melted at 224°.

Analysis.—0·0831 grm. gave 0·0897 grm. $BaSO_4$, whence S=14·8 per cent.

$C_8H_{12}ON_4S$ requires S=15·1 per cent.

Methiodide of 2-4-*dimethyl-thiazolyl*-5-*methyl ketone*, $C_7H_9ONS.CH_3I$.—This was prepared by heating the base with methyl iodide in a sealed tube for twelve hours at 90°. On crystallisation from alcohol, in which it is moderately soluble when cold, it was obtained in the form of colourless hydrated needles. The anhydrous salt melted at 197°.

Analysis.—0·0632 grm. gave 0·1292 grm. AgI, whence I=42·8 per cent.

$C_8H_{12}ONSI$ requires I=42·8 per cent.

4-*Methyl-thiazolyl*-2-*hydrazine hydrochloride*, $C_4H_7N_3S.HCl$.—Thiosemicarbazide was prepared according to the directions of Freund (Ber., xxix, 1896, 2500 per cent.).

Heat was evolved when thiosemicarbazide (10 grm.) was added in small portions to a mixture of monochloroacetone (10 grm.) and alcohol (5 c.c.). The reaction was moderated by cooling, and finally completed by heating on the water-bath for ten minutes. The reaction product, in which tarry decomposed substances were evident, was heated with dilute hydrochloric acid and filtered, the remaining oily impurities being removed from the filtrate by extraction with ether. On adding excess of caustic soda to a portion of the aqueous filtrate, an oily substance was produced which instantaneously changed to a black tarry substance, indicating that the base is very unstable.

The acid solution was therefore evaporated carefully to dryness in a current of air on the water-bath, when a certain amount of decomposition was evident. The semi-solid residue was extracted with a mixture of ether and alcohol, which removed most of the black decomposition products, leaving a brown crystalline mass.

This was dissolved in hot absolute alcohol containing some hydrochloric acid gas, and after filtration the solution was evaporated carefully to dryness. The residue of crystals was scarcely coloured, and appears to have been the somewhat impure mono-hydrochloride of 4-methyl-thiazolyl-2-hydrazine.

Analysis.—0·1059 grm. gave 0·1570 grm. $BaSO_4$, whence S=20·3 per cent.

$C_4H_7N_3S.HCl$ requires S=19·3 per cent.
0·1204 grm. gave 0·0993 grm. AgCl, whence Cl=19·4 per cent.
$C_4H_7N_3S.HCl$ requires Cl=20·4 per cent.

This salt dissolved easily in water, and addition of caustic soda gave a clear solution which darkened with great rapidity. On heating this salt

with sodium acetate and benzaldehyde in acetic-acid solution, no evidence of the formation of a thiazolyl hydrazone of benzaldehyde could be obtained.

The Authors desire to acknowledge gratefully financial assistance by the Research Grant Board, which defrayed part of the costs of the investigation.

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A NEW METHOD OF AERIAL SURVEYING. (THIRD PAPER.)

By H. G. FOURCADE.

(With seven Text-figures.)

In two previous papers on the same subject * the use of inclined plates was alone investigated because it seemed that, such plates being better conditioned, there was no need to develop the particular case of plates exposed in an approximately horizontal position. A number of other considerations, which will be discussed, make it however desirable to do so.

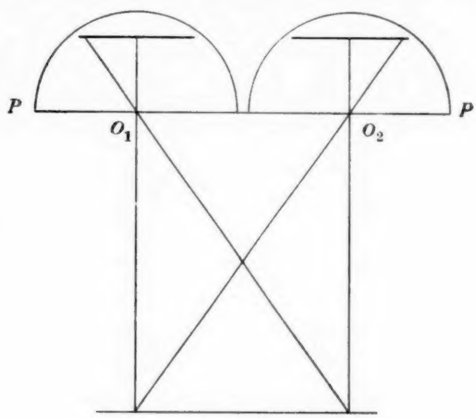


FIG. 1.

In the present paper the method is therefore applied to the simpler case of horizontal plates, and this leads in turn to some further simplifications in the treatment of inclined plates. Comparison of the respective advantages of horizontal and inclined plates is then made. Lateral extensions from aerial bases, and several other minor points, are also dealt with.

It will be recalled that the principle of the method is the setting, in a suitable instrument, of pairs of plates in correspondence—that is, in the

* Trans. Roy. Soc. S. Afr., vol. xiv, 1926, p. 93; and vol. xvi, 1928, p. 1.

relative positions in space they were exposed at, excepting scale. As was explained in the first paper, the images on the two plates of any one point are then in a common plane passing through the polar axis *PP* of the machine (fig. 1)—that is, have the same longitude on the spheres of reference centred at the back nodal points O_1O_2 of the lenses. The planes perpendicular at O_1 and O_2 to *PP* determine the equators of the plates. The plates are movable in the machine (*a*) in longitude, about the polar axis *PP*, either together or separately ; (*b*) in latitude about declination axes passing through O_1 and O_2 and perpendicular to the polar axis ; and (*c*) in position angle about axes through O_1 and O_2 and the respective principal points of the plates.

The polar angle, or difference in longitude, between points on the equator of a plate does not change appreciably for small rotations about

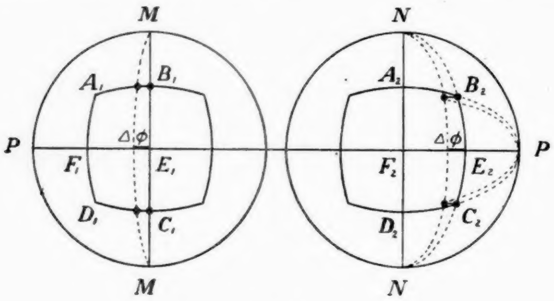


FIG. 2.

the declination axis, or small rotations of the position circle. Thus, in fig. 2, if the plates have been set in their approximately known positions the polar angle (B_1C_1) remains, for a small rotation $\Delta\phi$ of Plate 1 round its

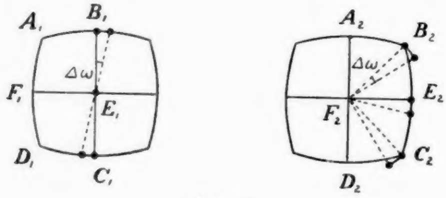


FIG. 3.

declination axis *MM*, nearly constant, while a similar rotation of Plate 2 causes the corresponding polar angle (B_2C_2) to vary. Again (B_1C_1) in fig. 3 is also not affected by a small rotation $\Delta\omega$ of the position circle of Plate 1.

Plate 2 may therefore be set in declination by operating the declination screw which moves its camera about the axis NN until the polar angle (B_2C_2) has become equal to (B_1C_1). This is accomplished by (*a*) setting B_2 in correspondence with B_1 by means of the difference screw coupling the two viewing cameras; (*b*) rotating the pair of cameras jointly until C_1 is bisected by the mark of the corresponding telescope; (*c*) removing half the discrepancy between C_1 and C_2 by altering the declination of Plate 2; and (*d*) resetting B_1 and B_2, or C_1 and C_2, in correspondence by means of the difference screw.

Plate 1 may be set in declination, in a similar manner, by making (A_1D_1) equal to (A_2D_2).

The polar angles (B_1C_1), (B_2C_2) and also (B_1E_1), (E_1C_1) of fig. 3 remain constant for small changes $\Delta\omega$ in the position angles of the plates, but (B_2E_2) and (E_2C_2) vary. Plate 2 may therefore be set in position angle by rotating its position circle until (B_2E_2) becomes equal to (B_1E_1), or (E_2C_2) equal to (E_1C_1), and, reciprocally, Plate 1 may be set by means of Plate 2. (B_2E_2) may be made equal to (B_1E_1) by successive approximation, with the help of the known factor connecting change in position angle with change in polar angle for the regions of the plate observed. A more direct procedure is the following: (*a*) set B_2 in correspondence with B_1 by means of the difference screw; (*b*) read on the position circle the rotation ω_1 required to bring E_2 in correspondence with E_1; (*c*) having reset the position circle to its first reading, thus restoring the correspondence of B_2 and B_1, set E_2 in correspondence with E_1 by means of the difference screw; (*d*) read the rotation ω_2 of the position circle required to restore the correspondence of B_2 and B_1. We have then, $\Delta\lambda$ being the difference between the polar angles (B_1E_1) and (B_2E_2) and ω the required rotation of the position circle of Plate 2.

$$p\omega_1=\Delta\lambda, \quad q\omega_2=\Delta\lambda, \quad (p-q)\omega=\Delta\lambda,$$

whence

$$\omega=\frac{p\omega_1}{p-q}, \text{ and since } p/q=\omega_2/\omega_1$$

$$\omega=\frac{\omega_2\omega_1}{\omega_2-\omega_1}$$

adapted for computation by logarithms or slide-rule, or, in another form,

$$\frac{1}{\omega}=\frac{1}{\omega_1}-\frac{1}{\omega_2}$$

adapted for the use of a table of reciprocals, such as Barlow's.

The difference in the longitudes of points having now been made equal

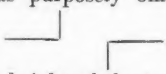
on both plates, it only remains to make the absolute longitudes the same by bringing with the difference screw the two images of any one of the points into correspondence.

The errors made in adjusting the plates in declination and position angle are of the nature of cosine errors, so that a second approximation should, as a rule, be amply sufficient to secure accurate correspondence.

Since the adjustments are independent of any necessary measurement or computation, and the reflectors remain in one position during the comparison of (B_2C_2) with (B_1C_1), and also in one position for (A_1D_1) and (A_2D_2), the settings in declination are not affected by errors of the scales, imperfection of the slides, inclination of the reflectors, or any instrumental errors other than imperfection of the pivots and relative eccentricity of the partial polar axes of the viewing cameras.

In setting for position angle one of the reflectors does rotate slightly when (B_2E_2) is compared with (B_1E_1), or (E_2C_2) with (E_1C_1), because E_2 is not on the parallel of latitude of B_2 and C_2, but the rotation is less than 1° in amount, and, if the vertical axis of the reflector is in fair adjustment, this rotation should not change sensibly the inclination of the reflector to the vertical.

If the pivots are made of hardened steel and equal in workmanship to those of a good theodolite their errors may be disregarded. The more serious error of eccentricity may be minimised by careful grinding of the four bearings to correct alignment when under load, by making the bearings adjustable, or, far better, by applying a simple method of coupling the camera bodies which eliminates the error. The only remaining errors will then be those resulting from errors of bisection.

Stereoscopic Marks.—Not every kind of stereoscopic mark is suitable for the setting of plates in correspondence. When the two pictures are not in exact register in height, the marks being more sharply defined may jump into coincidence and draw the pictures with them into an apparent combination in height blurred by defect in coincidence not easy to separate from faint definition of detail. For this reason, the marks devised by the writer for Model 1 of the War Office Stereogoniometer, in which a mapping attachment was purposely omitted, consisted of a non-combining pair arranged thus: , to obviate any interference with the free combination in height of the two pictures. Correspondence is attained by moving one of the pictures until the two horizontal branches appear to be in line.

When a mapping attachment forms part of the machine a stereoscopic travelling mark becomes indispensable for tracing the map features. The design represented in fig. 4 provides such a mark, while at the same time

the free combination of the pictures in height is maintained. The horizontal branches are non-combining, as in the previous case, but the broken vertical line of the one mark combines with some portion of the vertical line of the

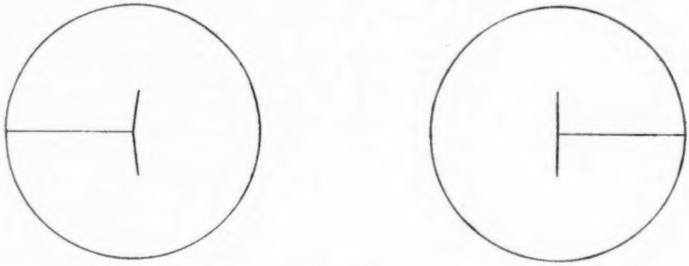


FIG. 4.

other mark to form an index in apparent relief which slides down to the junction of the horizontal lines as correspondence is reached.

Correspondence is, as a rule, not effected by bisecting any particular points, but by making the horizontal lines of the mark meet in the regions of the plate observed, so that even faint detail may serve.

Setting of Inclined Plates.—The method developed for setting horizontal plates in correspondence can also be applied without change to inclined

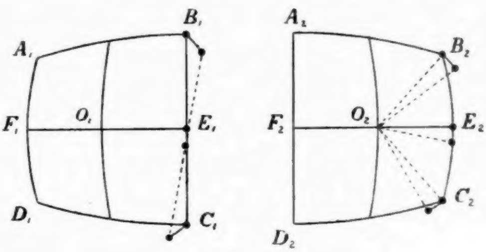


FIG. 5.

plates exposed fore and aft in a double camera. Each of these "linked plates" corresponds to one-half of a horizontal plate of nearly double the longitudinal field. In fig. 5, B_1C_1 becomes the equator of Plate 1 and A_2D_2 the equator of Plate 2, and the further procedure may remain the same. It differs from that given in previous papers by the use which is made of the polar angles (B_1E_1) and (B_2E_2) in setting for position angle.

Accuracy of Settings.—One result of this modification is that the effect on the settings of errors in correspondence can now be computed more

directly than heretofore. To make numerical comparisons of inclined and horizontal plates a value of 56° for the serviceable field of the lenses, which is practicable with an aperture of f/6·3, and an inclination, resulting from that value, of 40° between the axes of a double lens camera, will be assumed. Then F_2B_2 in fig. 2 and O_2A_2 in fig. 5 both equal 28°. This gives in fig. 2, $B_1E_1 = 20° \; 36' \; 20''$; and in fig. 5, $B_1E_1 = 20°$. From these values, and the formulæ on pp. 105–107 of the first paper, we get

Horizontal Plates.	Plates inclined at 20°.
$\Delta(B_2C_2) = 0{\cdot}248 \Delta\phi$	$\Delta(B_2C_2) = 0{\cdot}468 \Delta\phi$
$\Delta(B_2) = 0{\cdot}329 \Delta\omega$	$\Delta(B_2) = 0{\cdot}263 \Delta\omega$
$\Delta(E_2) = 0{\cdot}376 \Delta\omega$	$\Delta(E_2) = 0{\cdot}342 \Delta\omega$
$\Delta(B_2E_2) = 0{\cdot}047 \Delta\omega$	$\Delta(B_2E_2) = 0{\cdot}079 \Delta\omega$

in which $\Delta(B_2C_2)$ is the increment in polar angle of B_2C_2 for an increment $\Delta\phi$ in declination of Plate 2.

$\Delta(B_2)$ and $\Delta(E_2)$ are the increments in longitude of B_2 and E_2 for an increment $\Delta\omega$ in the position angle of Plate 2.

$\Delta(B_2E_2)$ is the increment in polar angle of B_2E_2 resulting from $\Delta\omega$.

If the probable error of the correspondence setting of a pair of points be taken at $\pm 2''$ the error of a correspondence in angle will be $\pm 2\sqrt{2} = \pm 3''$, that of a setting in declination $\pm \frac{2\sqrt{2}}{0{\cdot}468} = \pm 6''$ for an inclined plate and $\frac{2\sqrt{2}}{0{\cdot}248} = \pm 11''$ for a horizontal plate, and that of a setting in position angle taking the mean of the results from B_2E_2 and E_2C_2 $\pm \frac{2}{0{\cdot}079} = \pm 25''$ for an inclined plate and $\pm \frac{2}{0{\cdot}047} = \pm 42''$ for a horizontal plate. But the relative position angles of the two plates are also given directly by the much better condition that the polar angle of E_1F_1 on the one plate must be equal to the polar angle of E_2F_2 on the other plate. The error in relative position angle is thus reduced to $\pm \frac{2}{0{\cdot}342\sqrt{2}} = \pm 4''$ in the case of inclined plates and $\pm \frac{2\sqrt{2}}{0{\cdot}376} = \pm 7''$ in the case of horizontal plates. And, if the settings, previously obtained independently, are each corrected by half the discrepancy in relative position angle shown by E_1F_1 and E_2F_2, the error in position angle of either plate is reduced to

$$\pm \sqrt{\left(\frac{25}{2}\right)^2 + \left(\frac{25}{2}\right)^2 + \left(\frac{4}{2}\right)^2} = \pm 18''$$

for inclined plates, and

$$\pm\sqrt{\left(\frac{42}{2}\right)^2+\left(\frac{42}{2}\right)^2+\left(\frac{7}{2}\right)^2}=\pm 30''$$

for horizontal plates. It must be noted also that the actual error in position angle of a plate is not cumulative in a traverse, the error in relative position angle being alone carried forward.

Transfer of Vertical.—Optical markers are used for the purpose. As last designed, they consist of a mark movable in front of the plate and brought into focus by the interposition of a small lens through which the mark is seen. To mark a point, the point is first bisected in the telescope, and the marker being interposed, the cross of the latter is collimated with the sighting mark in the telescope. The marker may then move integrally with the plate.

A marker having been set to the vertical of one of the plates of a pair in correspondence is collimated with the appropriate telescope. The vertical on the other plate of the pair is then determined by a ray making an angle with the first sighting ray equal to the convergence of the two verticals, which is S/R, S being the length of the aerial base and R the radius of the Earth. The vertical thus located is marked by a second marker and its position recorded, if need be, by reading on the circles of the machine either the spherical plate co-ordinates of the point, referred to the plate axes, or its polar co-ordinates on the plate.

To transfer the vertical from one plate of a double camera to the other, set the first plate in position angle zero and declination C=half the angle between the camera axes. Read λ and ϕ the resulting spherical co-ordinates of Z. Then, on the second plate similarly set, the spherical co-ordinates of Z will be λ and $-\phi$. Setting these readings on the declination and main circles, the position of Z on the second plate may be marked by bringing the cross of the marker into collimation with the sighting line of the telescope.

Angles between Bases.—One method of measuring these was given at p. 9 of the second paper. Another solution is applicable to horizontal plates.

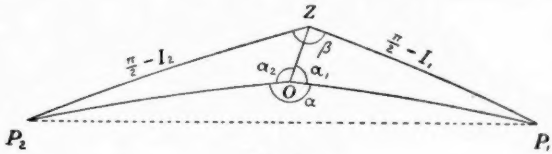


FIG. 6.

In fig. 6, let O be the centre of a plate, P_1 the pole given by the correspondence of the next plate to the right, and P_2 the pole given by the

correspondence of the next plate to the left. As before, the directions OP_1 and OP_2 can be marked on the plate when O is brought into the measuring plane of the machine. The angle P_1OP_2 may then be read on the position circle if O is set to declination zero. The inclinations I_1 and I_2 of the bases are known from previous determinations. Z being also known, α_1, α_2, and $i=OZ$ may be read. We have

$$\frac{\sin P_1}{\sin i}=\frac{\sin \alpha_1}{\cos \mathrm{I}_1}$$

$$\frac{\sin P_2}{\sin i}=\frac{\sin \alpha_2}{\cos I_2}.$$

P_1, P_2, i, and I_1, I_2 being all small angles,

$$P_1=i \sin \alpha_1$$
$$P_2=i \sin \alpha_2.$$

Applying the differential formula

$$dA=-\cos c dB-\cos b dC+\sin C \sin b da$$

to the spherical triangle OP_1P_2, we get, for $a=P_1P_2$ constant, $\mathrm{A}=a=2\pi-\alpha_1-\alpha_2$, $dB=P_1$, and $dC=P_2$,

$$\begin{aligned} da &= -P_1 \sin I_1 - P_2 \sin I_2 \\ &= -i(I_1 \sin \alpha_1 + I_2 \sin \alpha_2) \end{aligned}$$

and

$$P_1ZP_2=\beta=a-i(I_1 \sin \alpha_1+I_2 \sin \alpha_2).$$

The sign of the correction to a will be positive when Z is within the measured angle a, and negative when it is without.

Lateral Extension.—The cost of aerial survey consists largely of that of flying. It may be very much reduced by adding to the horizontal camera two others taking, at the same time, views inclined laterally to the line of flight. The settings of the lateral plates in the machine may then be derived at once from those obtained by the correspondence method for the adjacent horizontal pairs. Fig. 7 indicates the relative areas covered by a single camera with 50 per cent. side overlap of the plates and by a set of three cameras with the same actual overlap. With side cameras inclined at 40° from the vertical, flying miles, traverse computations, and correspondence settings are all reduced in the proportion of nine to one. Curvature and refraction may be provided for by altering the machine settings for the side plates by constants for any one scale. Such lateral extensions would be particularly valuable when flying parallel to a mountain range, or, for military purposes, when flying parallel to enemy trenches.

A pair of cameras taking fore and aft views might be substituted for

each of the three, but the mechanical complication imposed by automatic plate-changing, and simultaneous action of shutters in different planes, would become very great. The mechanism required to operate a triple camera is comparatively simple because there is one axis which is common to the three elements and can be made the basis of the movements.

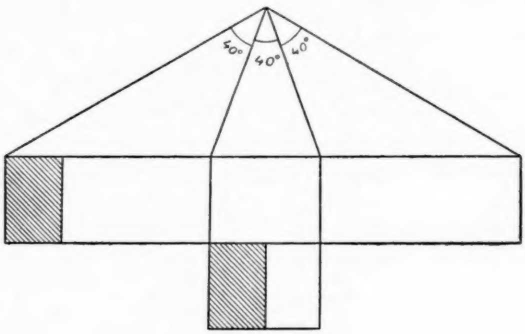


FIG. 7.

The Stereogoniometer requires no modification to be adapted for the use of lateral plates, except that it must have a longer drawing-board and longer mapping-rods if a scale larger than 1/20000, or thereabouts, is needed when the views are taken from a height of 10,000 feet above the ground.

Comparison of Horizontal and Inclined Plates.—The advantage of inclined plates is found in the greater precision with which pairs of plates may be set in correspondence, and in the reduction, by nearly one-half, of the number of points requiring to be fixed in an aerial traverse. We have seen that, for a probable error of $\pm 2''$ in the correspondence of points, the resulting errors in declination settings and position-angle settings are, respectively, $\pm 6''$ and $\pm 18''$ for plates inclined at 20°, and $\pm 11''$ and $\pm 30''$ for horizontal plates, while, for relative position angles, the respective errors are $\pm 4''$ and $\pm 7''$.

On the other hand, (*a*) if the settings of horizontal plates can be effected with sufficient accuracy for the ultimate purpose which, after all, is merely graphical mapping, it seems unnecessary to introduce the additional complication resulting from taking separately the fore and aft halves of the views from each station. (*b*) The errors made in linking together these two halves first in the camera then in the machine are avoided by the use of horizontal plates. The residual difference in distortion of two lenses is also eliminated since one suffices. (*c*) With the shorter, yet ample, aerial bases permitted by horizontal plates the depth of the stereoscopic

field * is nearly doubled, and, in consequence, the mapping may be continued without modification over the more mountainous areas. (*d*) Prints from horizontal plates, being a first approximation to a map, may serve at once for rough purposes, or may provide the material from which it is possible to construct a fairly accurate map by ordinary graphical methods after the vertical points have been marked with the Stereogoniometer or a simpler form of machine on the same principle. The advantage, for military purposes, is that a number of men without high technical qualifications can then be employed simultaneously on work made possible by one machine. (*e*) Lastly, and this is perhaps the main advantage, horizontal plates admit of the addition of lateral views without introducing undue mechanical complication in the camera.

On the whole, it seems probable that the balance of advantages will be found to lie with a triple camera taking one horizontal view and two lateral ones inclined at 20° transversely to the line of flight. The Stereogoniometer and its mapping attachment would remain the same, for they are equally well adapted to the use of both horizontal or inclined plates.

A Stereogoniometer, Model 1, has recently been constructed for the War Office by Messrs. Barr & Stroud of Glasgow, based on designs submitted by the author. In a recent communication from the War Office it is stated that, so far as experimental work has proceeded, "the machine has proved a striking success"; but, in the opinion of the author, details of construction will have to be modified in some respects before the theoretical accuracy of the method can be approached. Particulars of the machine, or of the results obtained with it, have not been published.

Witte Els Bosch,
April 1929.

* Trans. Roy. Soc. S. Afr., vol. xiv, 1926, p. 83.

NEW AND NOTEWORTHY MOSSES FROM SOUTH AFRICA.

By H. N. DIXON, M.A., F.L.S., and Professor H. A. WAGER, A.R.C.S.

(Descriptions by H. N. DIXON; Introductory Note by Professor WAGER.)

(Communicated by V. A. WAGER, B.Sc.)

(With Plate III.)

During the last few years several gatherings of Mosses from South Africa have resulted in the discovery of about a dozen species new to science, a few species hitherto unrecorded in South Africa, as well as the addition of a considerable number of new records of the rarer species. The purpose of this paper is to record and describe these.

It can be really considered as an addendum to Mr. Sim's work on the Bryophyta of South Africa. Sim's colossal work has removed practically all the chaos that has existed for such a long time in connection with South African Mosses. His book will undoubtedly be the standard work of reference for the Bryophyta of South Africa for many years to come. He has reduced about 850 recorded and named species of mosses, by means of synonyms, etc., to about 470. This is probably rather drastic, especially in the case of Sphagnum, Funaria, etc., and it is fairly certain that some of the names will have to be reabsorbed. With a little more collaboration Mr. Sim could have greatly increased the names of localities and thereby increased our knowledge of distribution.

South Africa has a fairly large Moss Flora, but much remains to be done in the way of a systematic survey. The mountains, kloofs, and forests are, of course, the chief hunting grounds for mosses, and where forests are in the mist belt like the Woodbush in the Transvaal, Karkloof in Natal, etc., mosses abound in profusion. There are enormous tracts of country practically devoid of mosses, although a moss like Archidium may sometimes be found in the open veld. Port St. John's, from which a number of new mosses and new records have been obtained, is not really a very good place for mosses. It was only by a systematic search that such good finds were obtained, and shows what would probably be the outcome of a systematic search in other places.

The nomenclature and classification in this paper follow in general that of Brotherus in Engler & Prantl, Musci, ed. i.

All the specimens were collected by Professor Wager unless otherwise specified.

SPHAGNACEAE.

Sphagnum fimbriatum Wils.—George, 1917 (No. 1057). c. fr.

This is not only the first record of this widely spread species, but is the first time that any species of Sphagnum has been found fruiting in South Africa.

The distribution of the species in the southern hemisphere is New Zealand, Chile, Patagonia.

Sphagnum capense Hornsch. var. **multiporosum** Warnst.—Belfast, Transvaal (886).

DICRANACEAE.

Archidium capense Hornsch.—Open country, Haaskloof, Transvaal, 1924 (14A).

Trematodon africanus Wag. (*T. ligulatus* Rehm. ined.).—Pretoria, 1924 (2A).

I have compared this with Rehmann, 22, Oakford, Natal. It agrees exactly with that. It cannot, however, be separated from *T. africanus*.

I cannot agree with Sim (Bryophyta of South Africa, p. 154) in making *T. ligulatus* Rehm. a synonym of *T. mayottensis* Besch. The latter is, as shown by Sim's figure, one of the most striking species of the genus in its vegetative characters, having broad, short, widely obtuse leaves with very short nerve. Rehmann's specimen does not show anything of this kind.

I take this opportunity also of commenting on Sim's reference of *T. intermedius* Welw. & Duby (p. 153) to *T. paradoxus* Hornsch. I do not think this can be upheld. I have examined Ecklon's specimen in herb. Schimper, and find that it agrees well with Roth's and Brotherus' descriptions, having the leaf subula very broadly ligulate and obtuse, with very lax cells. *T. intermedius* in all its forms has narrow subula and small cells.

Trematodon divaricatus Bry. eur.—Woodbush, Transvaal, 1923 (975).

Sim (*op. cit.*, p. 156) suggests that *T. divaricatus* is synonymous with *T. flexifolius*. In the latter, however, apart from any other character, the neck is inordinately long, fully twice the length of the capsule, and sometimes longer, while in *T. divaricatus* it is only equal to, or even shorter than, the capsule. *T. divaricatus* appears to me a quite good species. *T. Gueinzii* Mitt., MS., in herb. (near Durban, Port Natal, Gueinzius) is the same thing.

Ditrichum hymenodontium Dix. sp. nov.

E minoribus generis. Caespites densiusculi, perhumiles, virides. Caulis vix 5mm. altus. Folia erecto-patentia, sicca flexuosa, inferiora parva, superiora sensim longiora, comalia usque ad 3 mm. longa; e basi *brevissima paullo dilatata,* vix amplexicauli sensim in subulam angustissimam flexuosam integram vel summo apice minute denticulatam, plus minusve canaliculatam angustata. Costa latiuscula, *pessime definita.* Cellulae omnes lineares, perangustae, elongatae. Folia perichaetialia vix distincta. (Figs. 1*a*, 1*b*.)

Autoicum. Seta *tenuissima, flava,* circa 1 cm. longa. Theca *parva,* deoperculata 2 mm. longa, leptodermica, pallida, *erecta, symmetrica, breviter cylindrica, ad orem haud angustata*; operculum breviuscule rostratum, obliquum. Annulus latus, revolubilis.

Peristomium *pulchre rubellum,* breve, vix ·25 mm. altum; dentes apud basin arcte conferti, *inter se conjuncti, saepe dilatati, inde membranam basilarem plus minusve altam, papillosam,* instruentes, superne in crura *valde irregularia,* singula aut bina, filiformia, dense papillosa producta. Spori parvi, 8–10 μ.

Hab. Benoni, Transvaal, 1925 (1005).

Quite distinct from *D. flexifolium* in the small, erect, symmetric capsule, and the peristome, in which the teeth anastomose irregularly, the crura sometimes continuing narrow almost to the base, there anastomosing and very close, but more frequently dilated into a thin membrane, unusual in the genus (hence the specific name); most frequently the basal part of the teeth consists of two irregularly connected crura, which unite together into a single one above.

Dicranella minuta (Hampe) Besch.—Benoni, Transvaal, 1925 (1006).

Dicranella subsubulata (Hampe) Jaeg.—Belfast, Transvaal, 6600 ft. (845).

A form approaching in habit and leaf form *D. abruptifolia* (C.M.) and I think reducing the probability of the latter being distinct.

Sim refers *Aongstroemia abruptifolia* C.M. to *Ditrichum flexifolium,* and no doubt some of Rehmann's specimens consist of or contain that. The Kew specimen of Rehm. 25 consists of *Campylopus nanus.* The plant, however, described as *A. abruptifolia* by C. Mueller, as represented at the British Museum, is certainly a Dicranella, near *D. subsubulata,* but possibly distinct.

D. subsubulata was also sent me by Dr. Moss, collected by Mrs. Moss at King's Kloof, Transvaal, on damp, shady bank, in 1924 (10381).

Oreoweisia erosa (Hampe) Par.—Belfast, Transvaal, 6600 ft., 1919 (854).

The first record of this rare plant in recent years. In abundant, but mostly rather old fruit. The short, but abrupt and distinct neck is a marked character. Hampe's specimen has a single imperfect capsule only.

Holomitrium affine Card. & Thér. var. **cucullatum** (Besch.) Thér.—Van Reenen, 1917 (1052). Port St. John's, 1929 (1095).

Campylopus perpusillus Mitt.—Belfast, Transvaal (884, 1083).

Leucobryaceae.

Leucobryum Macleanum Rehm. in sched.—Belfast, Transvaal, 6600 ft., 1919 (862).

Sim subordinates this to *L. Gueinzii* C.M., perhaps rightly. Cardot, however, points out a character which separates them (Récherch. Anat. sur les Leucobryacées, pp. 13, 14), and which is usually considered of some importance in the genus, viz. the chlorocysts of the nerve in transverse section are hypercentric (*i.e.* nearer the ventral surface of the leaf) or centric in *L. Macleanum*; while in *L. Gueinzii* they are centric below and slightly hypocentric (*i.e.* nearer the dorsal surface) above.

Fissidentaceae.

Fissidens Wageri Wag. & Dix.—East London, 1918 (788). Perie Forest, Cape E., 1919 (828).

Fissidens aciphyllus Dix. sp. nov.

§ Reticularia. Plantae gregariae vel subcaespitosae, robustiusculae, *saturate virides, nitidae.* Folia plurijuga, siccitate parum mutata, leniter flexuosa, inferiora ovato-lanceolata, superiora anguste lanceolata, ad 2 mm. longa, acuminata, acute cuspidata; costa valida, fuscorubra, *percurrens*; limbus folii *validus*, aetate saepe fuscus, e cellulis 2–3-seriatis incrassatis instructus, integerrimus, ad apicem *cum costa confluens, atque cuspidem validam acutam instruens.* Areolatio laxa, e cellulis hexagono-rhomboideis circa 20–27 μ longis et 12–15 μ latis, basin versus sensim elongatis, composita, chlorophyllosa. (Figs. 2*a*, 2*a'*.)

Theca in seta breviuscula parva, *curvata, saepe inclinata vel cernua.* Peristomii dentes interne cristati.

Hab. Port St. John's, 1920, etc. (927, type, 943, 950, 1104). East London, 1919 (789).

Quite distinct from all the species of the section in the nerve reaching to apex, and in confluence with the stout border forming a robust, acute, cuspidate point. This is in fact at variance with the character given for the section, viz. "nerve ceasing below apex"; and I have hesitated whether it should be placed in Bryoidium, near to *F. Zollingeri* Mont., which has cells approaching it in size. There, however, the cells are clearly of a different type, being isodiametric, while here they are of the more or less elongate, subrhomboideal form characteristic of Reticularia, a character that must be held to outweigh the length of the nerve.

Fissidens cuspidatus C.M.—National Park, Natal, 1918 (737 bis). Belfast, Transvaal, 1919 (856). East London, 1918 (786). Kingwilliamstown (819).

Fissidens submarginatus Bruch.—Port St. John's (937, 957B). Bergville, Natal, 1918 (725). National Park, Natal, 1918 (735).

Fissidens remotifolius C.M.—National Park, Natal, 1918 (709, 761). Bergville, Natal, 1918 (728).

Fissidens pectinidens Dix. sp. nov.

? § Aloma. Gregarius. Stirps *perminuta*, saturate viridis. Caulis brevissimus, paucijuga; folia inferiora ovata, *acuta*, suprema anguste lanceolata, vix 1 mm. longa, tenera, marginibus omnino elimbatis, integerrimis; costa infra sat valida, superne angustata, *infra apicem evanida*, concolor. Lamina dorsalis angustissime decurrens, supra folii basin plerumque desinens. Cellulae superiores *chlorophyllosae*, subhexagonae, 10–13 μ latae, laeves, parietibus firmis, *haud incrassatis*; inferne elongatae, laxiores.

Seta circa 5 mm. alta, pallida; theca erecta vel inclinata, minuta, deoperculata circa ·5 mm. longa, ovalia, leptodermica, sicca ore dilatato, peristomio patente; dentes medio *alte cristati*. (Figs. 3*a*, 3*a'*.)

Hab. Port St. John's, 1920 (936).

A pretty little species, the place of which is not quite certain. The leaves are to all intents and purposes unbordered, but I have detected a perichaetial leaf here and there with the marginal cells of the vaginant lamina slightly elongate, and thus suggesting a border; the cells, however, are lax and subpellucid, not at all of the usual type of Semilimbidium cell; on the other hand neither are they of the usual character of Aloma, but rather of Bryoidium. The cristate lamellae of the peristome teeth also (as usual to be seen properly only in the dry state) are certainly not as a rule characteristic of Aloma. It is very near to *F. calochlorus* Dix. from the Victoria Falls, but that is of a much brighter green colour, with leaves broader at apex and more shortly pointed, and an extremely short seta.

Pottiaceae.

Weisia viridula (L.) Hedw. var. **brachycarpa** (C.M.) Dix. comb. nov.—Woodbush, Transvaal, 1923 (988). On clay loam, ridge at Kirstenbosch, Cape Peninsula, Aug. 1924; Pillans (4748).

Both these plants were referred to *Hymenostomum brachycarpum* (C.M.) Broth., no doubt rightly. On careful examination, however, I find that the capsule, while perfectly gymnostomous, is quite without hymenium at the mouth, and I have no doubt that it is a gymnostomous form of *W. viridula*, and that Sim is quite justified in reducing it to that. I have described

a var. *gymnostoma* from New Zealand, but that has some other characters which do not quite agree with the South African plant. I think it may well stand as var. *brachycarpa* (C.M.) Dix., distinguished from the type by the short, turgidly elliptic capsule, and the entire absence of peristome.

Weisia oranica (Rehm.) C.M.—Port St. John's (1085, 1106).

Sim places the South African plant under *W. crispata*, but though near it, it is—as species of this genus go—distinct enough, and must certainly be treated as different from the northern species. *W. crispata* is separated from *W. viridula* by the dioicous inflorescence, the stout nerve, 70 μ wide at base and often reddish, and the constantly calcareous habitat. The inflorescence is the only one of these characters that is shared by the South African plant, and I think it must be maintained as distinct.

Tortella caespitosa (Schwaegr.) Limpr.—Perie Forest, Cape E., 1919 (827, 830, 842). Port St. John's, 1929 (1107).

Much varying in leaf outline, as is the nature of the species. I have not the least doubt that *T. natalensi-caespitosa* (C.M.) and *T. eutrichostoma* (C.M.) belong here, as Sim suggests; the characters vary no more from the type than is common in Europe. Sim says of *T. eutrichostoma* that the leaves are longer and narrower, but C. Mueller describes them as *shorter*, and that is their character in Rehm. 91. I should feel the same with *T. Petrieana* Sim from the description and figures. Sim says it is easily distinguished from *T. caespitosa* by the hyaline cells ascending far up the margin; but that is the very feature that is so characteristic of *T. caespitosa*.

Weisiopsis pulchriretis Dix. sp. nov.

Caespitosa. Sordide viridis, humilis. Folia pro plantae magnitudine *longiuscula*, ad 4 mm. longa, faciliter emollita; e basi *angustata pallida* elongate lingulato-spathulata, *perconcava*, late acuta, marginibus *omnino planis*, integris. Costa ad basin valida, superne valde attenuata, *cum apice desinens*, concolor, dorso laevis. Cellulae *majusculae*, 12–15 μ latae, *pellucidae*, chlorophyllosae, *parietibus tenuibus*, dorso *humiliter mamillosae*; basilares *tenuissimae, hyalinae*, lineares, *parietibus tenuissimis*.

Paroica. Antheridia in foliorum superiorum plurimorum axillis. Seta *brevis*; circa 5 mm. longa, *pallida*. Theca minuta, ovalis, fusca, nitidiuscula, sicca leniter striata, *haud plicata*, exannulata. Operculum breviter tenuiter rostratum, cellulis in seriebus rectis, haud contortis. Peristomium *valde rudimentarium* videtur. (Figs. 4*a*, 4*a'*, 4*b*.)

Hab. National Park, Natal, 1918 (739).

The position of this plant is somewhat doubtful; the peristome appears to be entirely rudimentary (almost all the capsules are over-mature), but is clearly present, hence excluding Hyophila; while the large clear mamillose cells preclude Weisia. It seems to be fairly at home in Weisiopsis; cf. *W. Cardoti* Broth. (*Hyophila weisiaeformis* Card.) and *W. coreensis* (Card.)

Broth. It differs at once from the African *W. plicata* in the capsule not being plicate. The soft, pellucid leaves, with very narrow, hyaline base of thin-walled cells, widening out above so as to be narrowly spathulate, concave, and obtusely pointed, are quite different from any other South African allied plant I know. The paroicous inflorescence also is unusual, outside Weisia, and it may quite well ultimately prove to be the type of a new genus.

Didymodon afro-rubellus Broth. & Wag.—National Park, Natal, 1918 (689).

Barbula torquatifolia Geheeb.—*Cf.* Sim, Bryophyta of South Africa, p. 235. Mons. Thériot, in sending me a specimen from Nyasaland, says that the nerve structure shows it to be a Tortula.

Barbula afro-fontana (C.M.) Broth.—Port St. John's, in water, 1929 (1105). Lydenburg, Transvaal, 1929 (1109).

Phascum peraristatum C.M.—Kingwilliamstown, 1919 (809B).

This very rare little plant was found in an interesting association, with *Phascum leptophyllum*, and *Ephemerella nervosa* sp. nov.

Phascum leptophyllum C.M.—Kingwilliamstown, 1919 (809C). Belfast, Transvaal, 6600 ft. (848).

Pottia Macowaniana C.M.—Kingwilliamstown, 1919 (811).

Pottia subplano-marginata Dix. sp. nov.

A *P. Macowaniana* foliis *multo angustioribus, oblongo-lanceolatis, parum concavis,* costa validiore, marginibus *planis vel angustissime revolutis.* (Figs. 5*a*, 5*b*.)

Hab. Stellenbosch (671, type; 1054).

This pretty little species to some extent combines the characters of *P. afro-phaea* and *P. Macowaniana*. It has the narrow leaves of the former, with the margins plane or extremely narrowly recurved, but the cell structure is quite different, and the lid is very lowly and obtusely conical. On the other hand the fruiting characters are very similar to those of *P. Macowaniana*, as is also the cell structure, but the leaves there are much wider, very concave-carinate, with widely revolute margins, and the leaves are difficult to moisten out, while in the present plant they moisten out readily.

Tortula brevitubulosa Broth.—Goodoo Pass, Drakensberg, Natal, 1918 (742).

A rather taller plant than that originally described, and with longer seta, but otherwise quite agrees. It is a marked species in the very short tube of the peristome. On the other hand the leaves differ little from those of *T. erubescens*, *T. brachyaechme*, etc., which are mostly described from sterile or imperfect specimens, so that it is not quite certain that it may not belong to one of those. The leaves in 742 are fragile, but less remarkably so than is usual in that group.

GRIMMIACEAE.

Ptychomitrium marginatum (Wag. & Dix.) Dix.—Perie Forest, Cape E. (829, 886).

FUNARIACEAE.

Ephemerella nervosa Dix. sp. nov.

Ab omnibus speciebus africanis Ephemeri et Ephemerellae differt *costa, praecipue in foliis perichaetialibus superne valida, in aristam flexuosam longam excurrente.*

Protonema persistens. Planta circa 1 mm. alta; folia subsecunda, concavo-carinata, sensim acute acuminata, subintegra; perichaetii bracteae plerumque latiores, superne saepe cito angustatae atque dentibus nonnullis praeditae, inde per costam validam excurrentem longe aristatae. Theca ut in *E. sessile*, sed calyptra cucullata, sporique minores, 24–27 μ, globosi, tenerrime punctulati. (Figs. 6*a*, 6*a*′, 6*b*, 6*b*′.)

Hab. Kingwilliamstown, 1919 (809), type. Ibidem (1082B).

Differs clearly from *E. Rehmannii* (which I have not seen), e descr., in the larger spores, and the strong development of nerve; this varies a good deal, and may often be ill defined, but usually, and in the perichaetial bracts especially, it is stout and well defined, running out into a longish, undulate arista, at the base of which the margin is usually marked by a few irregular teeth.

The nerve also separates it from *E. sessile*, and the spores also are much smaller, and the cells much narrower and with thinner walls. The ♂ plant is mostly situated at the foot of the fertile stem.

It was associated with *Phascum leptophyllum* and *P. peraristatum.*

It is of course a moot point whether the genus Ephemerella, based on the cucullate calyptra, should be retained, or merged in Ephemerum.

Goniomitrium africanum (C.M.) Broth.—Pretoria, 1918 (764).

Hitherto known only from one or two localities in the O.F.S.

Physcomitrium spathulatum (Hornsch.) C.M.—I have received this from several South African localities, and they fully confirm the view that *P. poculiforme* Mitt., MS., is inseparable from *P. spathulatum.*

Funaria rufinervis Dix. sp. nov.

Entosthodon. Ab omnibus speciebus africanis peristomatis Entosthodontis raptim differt foliis *anguste acuminatis, ob costam validam rufam excurrentem longe aristatis.*

Folia late oblongo-ovata, *integerrima, vix marginata.* Seta brevis, circa ·75 cm.; theca omnino fere erecta, symmetrica, collo *distincto, subaequilongo.* Peristomium parvum, dentes imperfecti, irregulares, breves, rubri, papillosi. Spori 25–27 μ, plus minus tetrahedri, grosse muricati. (Figs. 7*a*, 7*b*, 7*c*.)

Hab. National Park, Natal (758).

A very distinct plant, like none of the other South African species. *F. Rottleri*, the leaves of which may sometimes resemble it, has an inclined, gymnostomous capsule.

Funaria marginata (C.M.) var. **obtusata** Sim.—National Park, Natal (706, 1056).

A very marked var., easily taken for a distinct species.

Funaria campylopodioides (C.M.) Broth.—Perie Forest, Kingwilliamstown (826). Summit of Zuurberg Range, Steynsberg, alt. 7000 ft., 1920, W. H. F. Alexander (4).

Variable in length of nerve, and doubtful if distinct from *F. Rottleri* (*cf.* Sim, Bryoph. of South Africa, p. 294).

Funaria transvaaliensis Broth., MS.—Pretoria, 1927 (1050).

I enter this with some hesitation, as the species is unpublished. Some time ago I wrote to Brotherus asking if it was not identical with *F. Hildebrandtii* (C.M.), and he replied that it differed from that in the leaf form, but without explaining the difference. I have not since then been able to compare it with *F. Hildebrandtii*, and do not feel able, therefore, to publish a description of it.

Funaria longicollis Dix. (*Entosthodon Dixoni* Sim).—Matoppos, Southern Rhodesia, 1921 (900).

The separation of Entosthodon from Funaria, followed by Sim, has necessitated some changes of nomenclature. I prefer on the whole to follow Brotherus in uniting them.

Bryaceae.

Mielichhoferia transvaaliensis C.M.—National Park, Natal, 1918 (703). Belfast, Transvaal, 1919 (852, 876, 883). Witpoortje, Transvaal, Feb. 1923, Bertha G. Mackay; distributed by the Brit. Bry. Soc., 1924.

The species is placed by Brotherus in a section having the peristome teeth appendiculate; they are scarcely so in No. 703. But C. Mueller describes them as *not appendiculate*, at most nodose. They exhibit a certain degree of variability in this respect, even in the same capsule.

Bryum Wilmsii C.M.—Haaskloof, Transvaal, 1925 (13A).

Bryum spinidens Ren. & Card.—National Park, Natal, 1918 (760).

The first record of this well-marked species in South Africa, and indeed the first occurrence in continental Africa, unless it should prove that *B. perspinidens* Broth. be a form of the same species, as seems quite possible in view of the variability of the plant (*cf.* Cardot, M. de Madagascar, p. 303). (Figs. 12*a*, 12*b*.)

Bartramiaceae.

Bartramidula globosa (C.M.) Broth.—National Park, Natal, 1918 (728).

Hedwigiaceae.

Braunia secunda (Hook.) **f. longipila.**—This form seems frequent, especially in Southern Rhodesia, and is often very marked. Also from National Park, Natal, 1918 (701).

Erpodiaceae.

Aulacopilum trichophyllum Aongstr.—East London, 1918 (779). Port St. John's, 1920 (934, 942). Pretoria, 1925 (1009).

Pterobryaceae.

Jaegerina stolonifera C.M.—Port St. John's, 1929 (1102).

This is an extremely interesting addition to the moss flora of South Africa. The genus is a small one, having a remarkable distribution. Of the six species known three are confined to the Mascarene Islands (including Madagascar); one (the present one) has a similar distribution but has also been found in South India, one species is confined to Jamaica, and one to the Philippines. (Figs. 8*a*, 8*b*, 8*c*.)

The usual form of *J. stolonifera* has long, little branched stems, throwing out microphyllous, stoloniform branches. The Port St. John's plant is shorter, more rigid, and more branched, and (in the small quantity I have received) without the stoloniform shoots. In this it agrees with the South Indian plant recently described as *J. stolonifera* var. *incrassata* P. de la Varde, though not in leaf form and other characters.

The plant (1102) was probably growing with or very close to *Calyptothecium Brotheri* (1103), judging from the numbering, and there is a very curious resemblance between the two plants (which have really no close affinity), both in the general habit and in the leaf form and structure. With the lens they can be at once separated, since the leaves of the Calyptothecium are, when dry, transversely undulated and rugose, while in the Jaegerina they are regularly and somewhat deeply longitudinally plicate. Under the microscope this distinction is scarcely obvious, and the leaves are remarkably similar. They may, however, be readily separated by the upper areolation. The cells in *Cal. Brotheri* are linear-rhomboid, only the apical ones more shortly rhomboid, and they have the cell walls strongly and irregularly incrassate and porose. (Figs. 9*a*, 9*b*.) In the Jaegerina the

upper cells are rather widely and quite shortly rhomboid-oval, the walls moderately wide, but quite equally thickened all round. The apex is also usually rather more sharply toothed than in the Calyptothecium.

The specimen is sterile.

Neckeraceae.

Papillaria africana (C.M.) Jaeg.—Woodbush, Transvaal, 1923 (976), c. fr.

The fruit, which is rare, is in very good condition. The calyptra, which I think has not been described, is densely pilose.

Thamnium pennaeforme (C.M.) var. **brachyphyllum** C.M.—Port St. John's, 1921 (954).

As I understand this variety, it is a very small-leaved form, the small, short leaves forming the primary character. Sim, however, treats it differently, taking *T. pennaeforme* (as *Porothamnium comorense*) as the usually dark green plant, with large leaves, broadly pointed and strongly toothed, and markedly complanate, and *P. natalense* (C.M.) (*P. pennaeforme* var. *brachyphyllum* C.M.) as the frequent form, often yellowish, with less complanate, often tapering branches, and more or less imbricate leaves, which are often rather pointed, and less strongly toothed, or entire.

These two forms are often very distinct, though there may be found frequent intergrading stages, and it seems quite reasonable to keep them separate. I am not clear, however, that that is what C. Mueller intended in drawing up his descriptions, as he described *P. pennaeforme* with the branches "saepius stolonaeo-caudatus," the branch leaves as sometimes "minora angustiora magis integriuscula"; while for *P. natalense* he insists on the smallness of the plant, the shortness of the branches, and the minute leaves. *P. pennaeforme*, according to C. Mueller, would then include the more robust forms of *both* sorts, and *P. natalense*, as I read it, would be only the very slender, small-leaved form.

The separation of Porothamnium from Thamnium appears to me entirely uncalled for; indeed I think it is very doubtful whether Thamnium and Porotrichum should not be united.

Entodontaceae.

Entodon brevirameus Dix.—Perie Forest, Cape E., 1919 (836).

Levierella fabroniacea C.M. var. **abyssinica** (Broth.) Dix.—National Park, Natal, 1918 (698).

A broad-leaved form.

Fabroniaceae.

Fabronia Leikipiae C.M.—Grahamstown, 1919 (803, 805).

Fabronia sp.—Kingwilliamstown (816).

A rather robust plant with pinnate stems, rather large, secund leaves, up to 1 mm. in length, widely lanceolate, subpiliferous, serrate, with a large alar group of large pellucid quadrate cells. It is probably a new species, but the material does not justify its publication. Fruit normal.

Helicodontium lanceolatum (Hampe & C.M.) Jaeg.—East London, 1918 (774, 783).

Sim is undoubtedly right in uniting *Schwetschkea Rehmannii* C.M. with this; but the plant is a true Helicodontium, with the peristome teeth striolate, not a Schwetschkea, which has the teeth papillose and not striolate.

Hypnofabronia Dix. gen. nov. Fabroniacearum.

Autoica. Fructus, ut videtur, Ischyrodontis. Sat robusta, habitu Amblystegioidea; folia laxa, flexuosa, ovato-lanceolata, latiuscule acuminata, concava. Costa variabilis, sub vel in acumine desinens. Cellulae laxae, pellucidae, rhomboideo-sigmoideae, basilares latiores, subrectangulares; marginales elongatae, lineares, incrassatae, limbum bene notatum subincrassatum per totum ambitum fere folii instruentes.

Perichaetii folia imbricata, interne subconvoluta, erecta, abrupte breviter acuminata, apud basin acuminis plus minusve grosse dentata vel laciniata. Theca minuta, turgide ovata, erecta, symmetrica; peristomium vetustum solum visum, dentibus indistincte per paria insertis, inferne latis, papillosis, teneris, haud striatis, apice destructis. Endostomium, ut videtur, nullum. Spori parvi. Operculum haud visum. Calyptra immatura nuda.

Hypnofabronia marginata Dix. n. gen. and sp.

Late caespitans, sordide rufo-viridis; caules valde intertexti, irregulariter, laxe ramosi, flexuosi, divagantes. Folia distantia, divaricata, siccitate parum mutata, contracta, ·5–·75 mm. longa, fragilia. Seta 5–6 mm. longa, crassiuscula, laevis; theca vix ·5 mm. longa, pachydermica. Cetera generis. (Figs. 10*a*, 10*b*, 10*b*′, 10*c*, 10*d*.)

Hab. South African Goldfield, 1870, leg. T. Baines; Herb. Mitten as "Helicodontium."

A very remarkable plant, which might be described as like a slender form of Sciaromium Lescurii (Sull.), but of softer texture, with fruit of Fabronia. Unfortunately the peristome is much worn, and its exact structure is uncertain; enough, however, remains to show that the outer teeth are broad below, almost touching one another, and indistinctly arranged in pairs; thin of texture, and papillose, not striolate, on the dorsal surface. They are therefore, more or less, like Schwetschkea or

Ischyrodon, but the vegetative characters are totally unlike anything else in the Family. The perichaetial leaves, abruptly short-pointed and often coarsely toothed at the base of the acumen, also recall Fabronia.

The leaf cells are lax and pellucid, quite Amblystegioid, and the border very distinct, slightly thickened and brownish, and surrounding practically all the leaf.

Hookeriaceae.

Cyclodictyon vallis-gratiae (Hampe) Broth.—Port St. John's, 1921 (949).

Hookeriopsis Pappeana (Hampe) Broth.—Port St. John's, 1929 (1111).

Leskeaceae.

Lindbergia haplocladioides Dix.—Grahamstown, 1919 (820).

Pseudoleskeopsis pseudo-attenuata (C.M.) nov. var. **perfecta** Dix.

Stirps habitu Pseudoleskeae, *e.g. P. Macowaniana*, persimilis, et vix distinguenda nisi caracteribus fructiferis. Rete tamen magis pellucidum, minus obscurum videtur.

Peristomium generis, majusculum; dentes optime marginati, processus aequilongi; cilia 1–2, subaequilongi, filiformia; endostomium omne papillosum, membrana basilaris circa tertiam partem dentium aequans. (Fig. 11.)

Hab. Belfast, Transvaal, 6600 ft., 1919 (853). Macomo's Hoek, South Africa, Jan. 1897, coll. Mrs. Clarke Williams, herb. Mitten, as *Pseudoleskea claviramea* (C.M.).

The long, filiform cilia, almost equalling the processes and teeth in length, place this in Pseudoleskeopsis, and I cannot find any very definite characters of importance to separate it from the Asiatic *P. orbiculata* Mitt. The genus, however, seems to me very insecurely founded, depending entirely on the full development of the cilia. Some of the species are dioicous, and that has been considered a generic character; Fleischer, however, states that *P. Zippelii* (Doz. & Molk.) is autoicous, and the present plant is certainly so.

Moreover, I have seen *Pseudoleskea Macowaniana* with cilia distinctly better developed than is usually the case, and forming, therefore, a link between the genera.

The plant from Macomo's Hoek was sent me from the New York Bot. Gard. I also received what is evidently a duplicate from Rev. C. H. Binstead as *Leskea claviramea* C.M., but in the former case the collector was given as Mrs. Clarke Maxwell, and in the latter as Mrs. Clarke Williams. I do not know which is correct.

The median cells are short and obscure, not elongate as given by Sim

for *P. Macowaniana*; but I doubt whether the latter character is reliable; I have been unable to verify it on some specimens of *P. Macowaniana*.*

Sematophyllaceae.

Rhaphidostegium Wageri (Wright & Wager) Dix.—National Park, Natal, 1918 (705). Pretoria, 1918 (757). Bergville, Natal, 1918 (719).†

Rhaphidostegium sphaeropyxis (Rehm.) Jaeg.—Port St. John's, 1920 (925).

The narrow, strict leaves, plumosely spreading, give this species an unusual appearance.

* Since the above was in the hands of the printer a very valuable paper has appeared by Thériot, *Le genre Pseudoleskeopsis* (Ann. de Cryptogamie Exotique, ii, 5). In this paper the author points out that Pseudoleskeopsis as described by Brotherus is a very ill-defined genus, and that the species of Pseudoleskea § Pseudo-pterogonium Broth. have much closer affinity with it than they have with the remaining species of Pseudoleskea (§ Eu-Pseudoleskea Broth.). He therefore removes the species of Pseudo-pterogonium (with three exceptions) from Pseudoleskea, and unites them with Pseudoleskeopsis as a separate section.

All the S. African species hitherto placed in Pseudoleskea are therefore (with the doubtful exception of *P. capilliramea* C.M.) removed to Pseudoleskeopsis.

This entirely coincides with the conclusion I had arrived at, as remarked above, with regard to the relationship between certain of the S. African plants and the genus Pseudoleskeopsis, and the unsatisfactory delimitation of that genus from Pseudoleskea, and results in a much more satisfactory grouping of the species; although the same result would have been attained, and possibly in a more satisfactory manner, by dropping the genus Pseudoleskeopsis altogether and uniting the species with Pseudoleskea § Pseudopterogonium.

Thériot's grouping of the S. African plants is as follows :—

1. *Pseudoleskeopsis claviramea* (C.M.) Thér. A fairly distinct species.
2. *Pseudoleskeopsis pseudo-attenuata* (C.M.) Thér., with two varieties :
   var. *acuminata* (Rehm.)Thér. (*Pseudoleskea claviramea* var. *acuminata* Rehm.).
   var. *Macowaniana* (C.M.) Thér.

This species is distinct from *P. claviramea* in the branches often attenuated, the leaves mostly secund, and more acuminate. The vars. appear to be of slight importance.

3. *Pseudoleskeopsis leskeoides* (Schimp.) Thér.

Distinguished from (2) by the leaves of decidedly narrower outline, narrowly ovate-lanceolate rather than widely ovate-acuminate.

I had at first described the above plants (853, and Mitten's specimen) as a new species; the peristome removing it from Pseudoleskea as then understood. Owing to the rearrangement I have now been able to reduce it to a var. nov. of *Pseudoleskeopsis pseudo-attenuata*, based on the peristome alone, a position much more in accordance with the actual relationships.

† This is *Sematophyllum Wageri* of Sim, Bry. of S. Africa, p. 435. It is probable that the name Rhaphidostegium will have to be replaced by Sematophyllum, but it is one of those points of nomenclature awaiting settlement, and I have retained the name in general use for the present.

Rhaphidostegium caespitosum (Sw.) var. **gracile.**—Port St. John's, 1929 (1092). A slender, graceful form with rather distant leaves, which I take to be the var. described and figured by Sim (Bry. of South Africa, p. 437). I am not aware who is the author of the varietal name.

BRACHYTHECIACEAE.

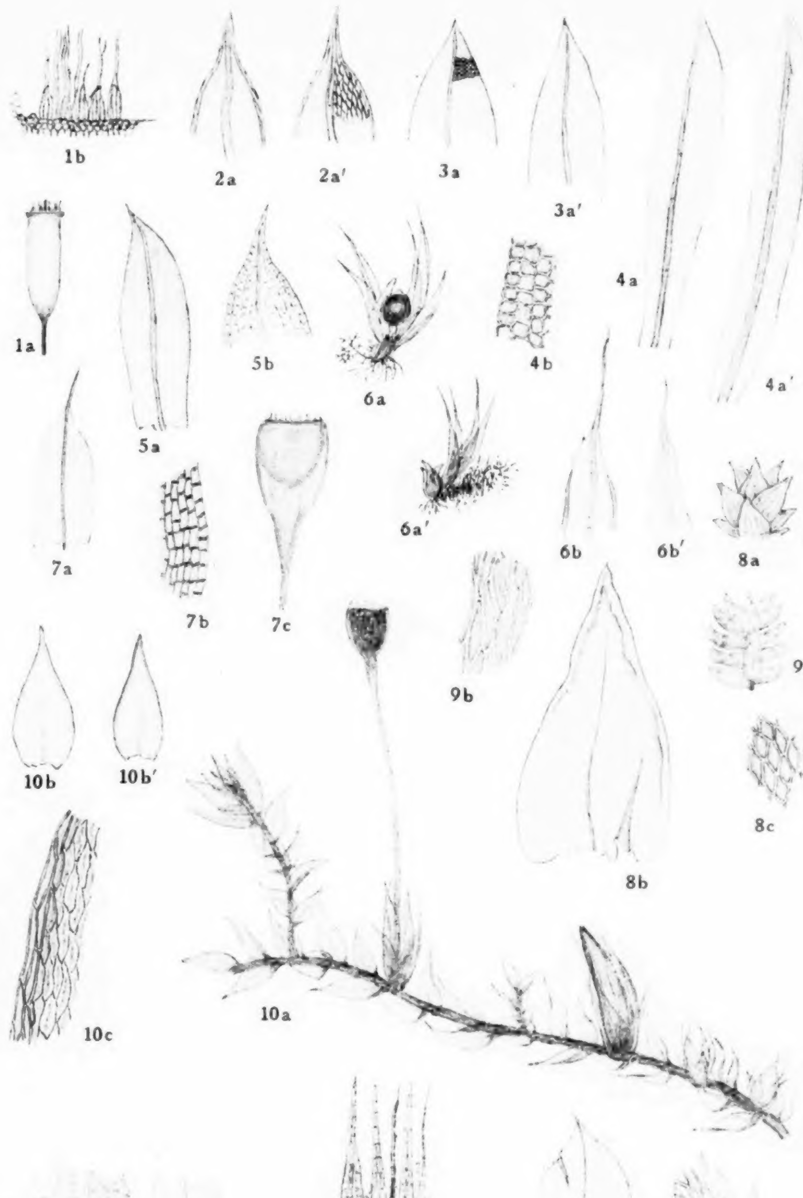
Rhynchostegiella algiriana (Brid.) Broth.—Port St. John's, 1921 (953). A slender form, which is probably *R. pertenella* (Ren. & Card.). Umtali, Southern Rhodesia, 5200 ft., on rock and tree roots in forest, 1926, F. Eyles (4663).

I cannot separate these in any way from Bridel's species, which appears to be distributed throughout Africa, though not yet recorded for S. Africa.

Oxyrrhynchium Macowanianum (Par.) Broth.—Perie Forest, Cape E., 1919 (824). Port St. John's, 1921 (929).

EXPLANATION OF PLATE.

1. *Ditrichum hymenodontium.* (*a*) Capsule, ×6; (*b*) part of peristome, × 50.
2. *Fissidens aciphyllus.* (*a, a′*) Leaf apices, ×40.
3. *Fissidens pectinidens.* (*a*) Lower, (*a′*) upper leaf apices, ×40.
4. *Weisiopsis pulchriretis.* (*a, a′*) Leaves, ×20; (*b*) upper cells, × 200.
5. *Pottia subplano-marginata.* (*a*) Leaf, ×20; (*b*) apex of leaf, ×40.
6. *Ephemerella nervosa.* (*a, a′*) Fruiting and ♂ plants, ×15; (*b, b′*) apices of perichaetial leaves, ×40.
7. *Funaria rufinervis.* (*a*) Leaf, ×10; (*b*) upper marginal cells, ×50; (*c*) capsule, ×12.
8. *Jaegerina stolonifera.* (*a*) Part of branch, dry, ×3; (*b*) leaf, ×15; (*c*) upper cells, ×200.
9. *Calyptothecium Brotheri.* (*a*) Part of branch, dry, ×3; (*b*) upper cells, ×200.
10. *Hypnofabronia marginata.* (*a*) Part of stem, ×8; (*b, b′*) leaves, ×20; (*c*) upper marginal cells, ×200; (*d*) part of peristome, ×100.
11. *Pseudoleskeopsis pseudo-attenuata* var. *perfecta.* (*a*) Part of peristome, ×50.
12. *Bryum spinidens.* (*a*) Leaf, ×4; (*b*) upper marginal cells, ×50.



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